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A description and comparative analysis of two competing automated SHORAD-C2 systems.

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THESIS

A DESCRIPTION AND COMPARATIVE ANALYSIS OF
TWO COMPETING AUTOMATED SHORAD-C2 SYSTEMS

by

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March 1983

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The U.S. Army is attempting to provide air defenders with a command and control system that offers the speed and accuracy required to combat the aerial threat to the division. This thesis analyzes two competing proposals for an automated Short Range Air Defense (SHORAD) C2 system. The analysis is based on constraints and criteria developed by the Army Air Defense Center

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A Description and Comparative Analysis of Two Competing Automated SHORAD-C2 Systems

by

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Captain, United States Army
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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

The U.S. Army is attempting to provide air defenders with a command and control system that offers the speed and accuracy required to combat the aerial threat to the division. This thesis analyzes two competing proposals for an automated Short Range Air Defense (SHORAD) C2 system. The analysis is based on constraints and criteria developed by the Army Air Defense Center and from requirements deemed necessary by the author. It is suggested that proposals by other manufacturers undergo a similar analysis to provide the earliest possible deployment date.

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LIST OF ABBREVIATIONS AND ACRONYMS

A/C - Aircraft

ACAB - Air Cavalry Attack Brigade

ADA - Air Defense Artillery

ADCN - Air Defense Coordination Net

ADCO - Air Defense Coordination Officer

ADCS - Air Defense Coordination Section

AHB - Attack Helicopter Battalion

ALO - Air Force Liason Officer

AM - Amplitude Modulation

AMSAA - Army Materiel System Analysis Activity

ASL - Authorized Stockage List

AVLB - Armored Vehicle Launched Bridge

BCT - Briefcase Terminal

BDE - Brigade

BSA - Brigade Support Area

C2 - Command and Control

CACDA - Combined Arms Combat Development Activity

CAC - Combined Arms Center

CAS - Close Air Support

CE - Communications Electronics

CEWI - Combat Electronic Warfare Intelligence

COMMINT - Communications Inteligence

CP - Command Post

CRC - Control and Reporting Center

CRP - Control and Reporting Post

CSAB - Combat Support Aviation Battalion

CSAC - Combat Support Aviation Company

DADC2 - Division Air Defense Command and Control

DAME - Division Airspace Management Element

DCD - Directorate Combat Development

DCT - Digital Communication Terminal

DISCOM - Division Support Command

DIVAD - Division Air Defense

DMMC - Division Material Management Center

DRS - Division Restructuring Study

DS - Direct Support

DTAB - Division Target Acquisition Battalion

DTOC - Division Tactical Operations Center

ECM - Electronic Counter Measures

EMCON - Emissions Condition

ELINT - Electronic Intelligence

ESM - Electronic Support Measures

EWBN - Early Warning Broadcast Net

FA - Field Artillery

FAAR - Forward Area Alerting Radar

FACP - Forward Air Control Post

FEBA - Forward Edge of the Battle Area

FM - Frequency Modulation

FU - Fire unit (s)

GEOREF - Geographic Reference

GS - General Support

GSAC - General Support Aviation Company

HEIT-SD - High Explosive Incindary Tracer-Self Destruct

HF - High Frequency

HHB - Headquarters and Headquarters Battery

HHC - Headquarters and Headquarters Company

HIMAD - High-to-Medium Altitude Air Defense

HUMINT - Human Intelligence

ICHAP - Improved Chaparral

IFAAR - Improved Forward Area Alerting Radar

IFF - Interrogation Friend or Foe

IHAWK - Improved HAWK

IMINT - Image Intelligence

JFAAD - Joint Forward Area Air Defense

JTIDS - Joint Tactical Information Distribution System

LADS - Light Air Defense System

LNO - Liason Officer

LOA - Letter of Agreement

LOS - Line-of-Sight

MANPADS - Man Portable Air Defense System

MICOM - Missile Command

MLRS - Multiple Launcher Rocket System

MSCS - Manual SHORAD Control System

MSR - Main Supply Route

MTI - Moving Target Indicator

NBC - Nuclear, Biological, and Chemical

OPSEC - Operations Security

PLL - Prescribed Load List

PLRS - Position Location Reporting System

POW - Prisoner of War

RATT - Radio and Teletype

REFORGER- Return Forces to Germany

RF - Radio Frequency

RFDL - Radio Frequency Data Link

RFP - Request For Proposal

ROAD - Reorganization Objective Army Division

RPV - Remotely Piloted Vehicle

RTO - Radio Telephone Operator

SHORAD - Short Range Air Defense

SIGSEC - Signal Security

SP - Self Propelled

TAC CP - Tactical Command Post

TADDS - Target Alert Data Display Set

TAMC - Transportation Aviation Maintenance Company

TOC - Tactical Operations Center

TRADOC - Training and Doctrine Command

TRASANA - Training and Systems Analysis Activity

TST - Transmission Scheme Translator

USAADS - U.S. Army Air Defense School

UTM - Universal Transverse Mercator

I. FOCAL RESEARCH INTEREST

A. INTRODUCTION

The U.S.Army air defense community is facing a period of significant change. New weapon systems are being fielded while tactics, doctrine and command and control (C2) systems to maximize the effectiveness of the new weapon systems are being developed and improved upon. Ground based air defense activities impact on the airspace over the ground forces. This necessitates a joint effort between the Army and the Air Force in the development of doctrine and command and control systems to (1) provide maximum air defense protection and (2) enhance friendly aircraft survivability.

The Joint Forward Area Air Defense (JFAAD) office of Training and Systems Analysis Activity (TRASANA) has proponency for the joint service problems of airspace management and aircraft identification. Concurrently the short range air defense (SHORAD) C2 project manager's office has proponency for developing an Army SHORAD-C2 system. Requirements for a new C2 system are a composite of user inputs from the U.S. Army Air Defense School (USAADS) at Ft. Bliss, Tx. and parameters based on MICOM analysis efforts. Meanwhile, several companies have already developed hardware, software and/or system design concepts to improve upon current SHORAD-C2 capabilities.

B. OBJECTIVE

The objective of this thesis is to describe two competing automatic SHORAD-C2 systems (system capabilities) and to evaluate them against operational requirements (identify shortfalls). Both systems, one by Defense Systems Division of Sanders Associates and the other by Litton Data Systems, were developed with off the shelf capabilities.

C. BACKGROUND

1. U.S. Army Air Defense

Air defense weapon systems can be divided into two categories: (1) systems that support high-to-medium altitude air defense (HIMAD) which typically engage aircraft above 5000 feet and, (2) systems that are classified as short range air defense (SHORAD) which engage aircraft below 5000 feet. Figure 1 depicts the unclassified engagement envelops of the various systems to assist in system definition and classification.

The weapon systems that are currently in the HIMAD category are IHAWK, Patriot and Nike Hercules. HIMAD weapon systems are either corps or theater assets though they may be deployed in the division area and/or in direct support of the division. HIMAD has automated C2 systems with adequate capabilities and will not be pursued in this thesis.

SHORAD systems consist of the Vulcan, Chaparral and Stinger with the Division Air Defense (DIVAD) gun to be

fielded in the near future as a replacement for the Vulcan. SHORAD units can be designated as either divisional or non-divisional. The emphasis of this research effort will focus on the C2 capabilities of division SHORAD systems.

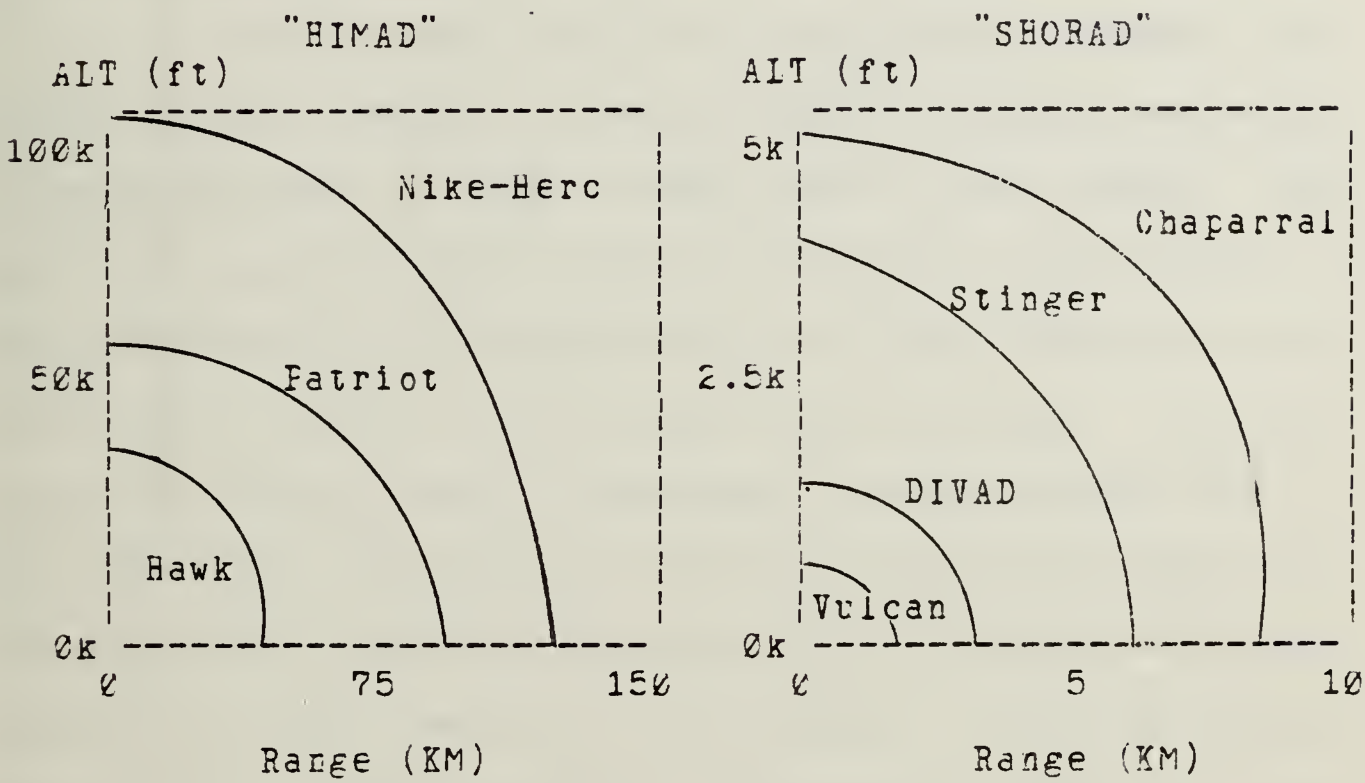


Figure 1. Engagement Envelopes

2. SHORAD Family

a. Vulcan

The Vulcan is a surface-to-air gun system that consists of a six barrel, 20-mm, automatic cannon mounted either on a tracked armored chasis (self-propelled) or on a trailor chasis (towed) to be pulled by a 1 1/4 ton or larger vehicle. Both systems are equipped with on-vehicle intra-communications between crew members, as well as, voice radio communications to platoon and/or supported unit nets. The

other major components of the system are a sighting system consisting of a lead-computing sight, a telescope, a night vision sight, and a range only radar. The range only radar provides input to the lead-computing sight once the operator is tracking the target.

The cannon is an electrically powered, air cooled rotary weapon. It fires electric primer ammunition at selected rates of 1000 or 3000 rounds per minute. The operator may also select the burst length of 10, 30, 60, or 100 rounds while in the high rate of fire mode and has continuous control in the low rate of fire. The self-propelled Vulcan has an on-board storage capability of approximately 1100 rounds. The towed Vulcan can only carry 500 rounds but, has the advantage of a limited reloading capability while remaining in action. The air defense ammunition is high explosive incendiary tracer -- self destruct (HEIT-SD). It is self-destructing to prevent injury and/or damage to friendly ground forces since the air defense mission requires 360 degree engagements. The time of flight before self-destructing limits the range to approximately 1200 meters.

Both versions (SP and towed) are capable of high speed travel on improved roads while the SP has a better rough terrain capability. The SP Vulcan can perform limited amphibious operations. The towed version has the advantage of being air transportable by the CH-47 and the Blackhawk

helicopters. For this reason, airborne, air assault and light infantry divisions normally are equipped with towed Vulcan, while mechanized and armor divisions are authorized the SP.

b. Division Air Defense (DIVAD) Gun

The DIVAD is a surface-to-air gun system that consists of a twin barrel, 35mm, automatic cannon mounted on an M-48 tank chasis. The system has an on-board target acquisition and interrogation capability. The vehicle is equipped with intra-communications between crew members and radio communications with higher headquarters.

The automatic tracking systems allow the system to shoot while on the move. This system also improves the overall system lethality which results in decreasing ammunition expenditure.

c. Chaparral

Chaparral is a self-propelled, surface-to-air guided missile system consisting of two major subsystems; the carrier and the launching station. The carrier is an unarmored full-tracked vehicle capable of cross country travel as well as moderate speeds over improved roads. The carrier, with system and crew, can ford streams up to 40 inches in depth and with the swim kit installed can cross water barriers as long as waves do not exceed one foot.

The launching station is an independent weapon system capable of launching missiles when mated to or

separated from the carrier. The launching station, therefore, can be airlifted by CH-47 helicopter to a remote location for special operations. The launching station carries twelve missiles, four on launch rails and eight in storage compartments. There are two major components to the launching station, a base structure and a mount which contain the seven sub-systems: power, mount erection-retraction, mount drive, missile control and launch, missile air, environmental control, and communications. The base structure merely houses some of the functional subsystems while the mount provides the gunner the means for aiming and launching missiles. There is an ongoing modification program to upgrade all Chaparral systems by adding an identification friend or foe (IFF) capability.

The missile is a supersonic surface-to-air modified Sidewinder missile that uses a passive infrared (IR) target detection and a proportional navigation guidance control system. The guidance section senses the IR radiation of the target to determine the direction to the target and generates signals to the control fins. The improved missile is capable of engageing aircraft flying directly at the weapon system and has the feature of a smokeless rocket motor which leaves no trail back to the weapon system. Considered a "fire and forget" system, there is no control nor failsafe capability from the ground once the missile is launched. The target detecting device acts

as a proximity fuze as well as a means for destruction on contact.

d. Stinger

The Stinger is a man portable air defense (MANPAD) shoulder fired system whose major components consist of a missile and a launcher unit. The launcher has several components to enable the gunner to aim, track, interrogate, lock-on and fire on hostile targets. The interrogation function is performed thru IFF equipment attached to the launcher.

The missile is a supersonic, surface-to-air missile that also uses passive IR homing and proportional navigation guidance. The seeker is capable of locking on and engaging head on aspect targets despite the shielding of the majority of the IR source by the aircraft. The system uses a one shot and throw away concept and, like the Chaparral, possesses the fire and forget characteristic. This enables the team to move immediately after firing, to enhance crew survivability.

Stinger teams are authorized a 1/4 ton utility vehicle (jeep) with a trailer. This provides crew and equipment with battlefield mobility as well as a command post. The team can operate independent of the vehicle with a reduced missile capability. The radio can be removed from the vehicle mount and used as a backpack radio.

3. <u>SHORAD Mission/Organization</u>

a. Mission

The division air defense officer, SHORAD battalion commander, is responsible for providing air defense protection to assets within the division area. He must utilize the available SHORAD systems to maximize coverage of critical assets and minimize damage from aerial attack. There are four basic missions that the air defense units must be able to accomplish. Table I shows the distribution of missions by percentage of time a SHORAD unit in a heavy division could expect to be engaged in a particular type of defense as well as general location within the division area. [Ref. 1]

TABLE I

SHORAD MISSIONS

Mission		Location Behind FEBA
	100%	
Maneuver Unit Defense		0 - 5 KM
	50%	
Forward Area Critical Asset Defense		10 - 25 KM
	40%	
Rear Area Critical Asset Defense		25 - 40 KM
	5%	
Convoy Defense		5 - 40 KM
	0%	

b. Battalion Organization

The typical SHORAD battalion consists of a headquarters battery and four firing batteries. The sensor platoon is organic to the headquarters battery. The firing batteries each have four firing platoons. One of the four platoons in each battery is a Stinger platoon. The other three platoons are all Vulcan in a Vulcan battery and all Chaparral in a Chaparral battery (see Figure 2).

```
                                  --------
                                 | SHORAD |
                                 |   BN   |
                                  --------
                                      |
                 ----------------------------------------
                |                     |                   |
             --------              -------           -----------
            | VULCAN |            |  HHB  |         | CHAPARRAL |
            |  BTRY  |             -------          |   BTRY    |
             --------  x2             |              -----------  x2
                |                  -------                 |
             ---------            | FAAR  |          ------------
            |         |           |  PLT  |         |            |
  ---------   --------             -------     ---------   -----------
 | STINGER || VULCAN |                        | STINGER | | CHAPARRAL |
 |   PLT   ||  PLT   |                        |   PLT   | |    PLT    |
  ---------   --------  x3                     ---------   -----------  x3
```

Figure 2. SHORAD Battalion Organization

The Chaparral/Vulcan platoons are authorized four weapon systems for a total of twelve in each type battery and twenty-four of each system within a division. (Airborne/Air assault divisions have only towed Vulcan and will not be described here.) When tactically deployed, the firing batteries are normally task organized by platoons to

provide maximum protection to the assets that the division commander has designated as air defense priorities. The general rule for weapon system deployment is to utilize the mobility of Stinger and Vulcan systems forward with the maneuver units while Chaparral supports division rear area assets.

Though the Stinger systems are organic to the SHORAD battalion, the number of teams that are authorized is based on the number of infantry, armor, field artillery battalions and armored cavalry squadrons in the division. The total number of teams will vary depending upon how many battalions/squadrons are in a given type division. For example, a mechanized infantry division with ten battalions is authorized 67 teams. In this type division then, there are a total of 115 firing units where each SHORAD weapon system constitutes a firing unit.

4. Early Warning

When SHORAD weapon systems were first fielded in the mid 1960's, it became readily apparent that a system for alerting fire units to aircraft approach was essential. "Figure 3 is a summation of the results of many studies that provided quantitifiable information...that--alerted SHORAD gunners perform better than non-alerted gunners." [Ref. 2] These early studies led to the current C2 procedures in the field today and are providing the basis for advance SHORAD-C2 development.

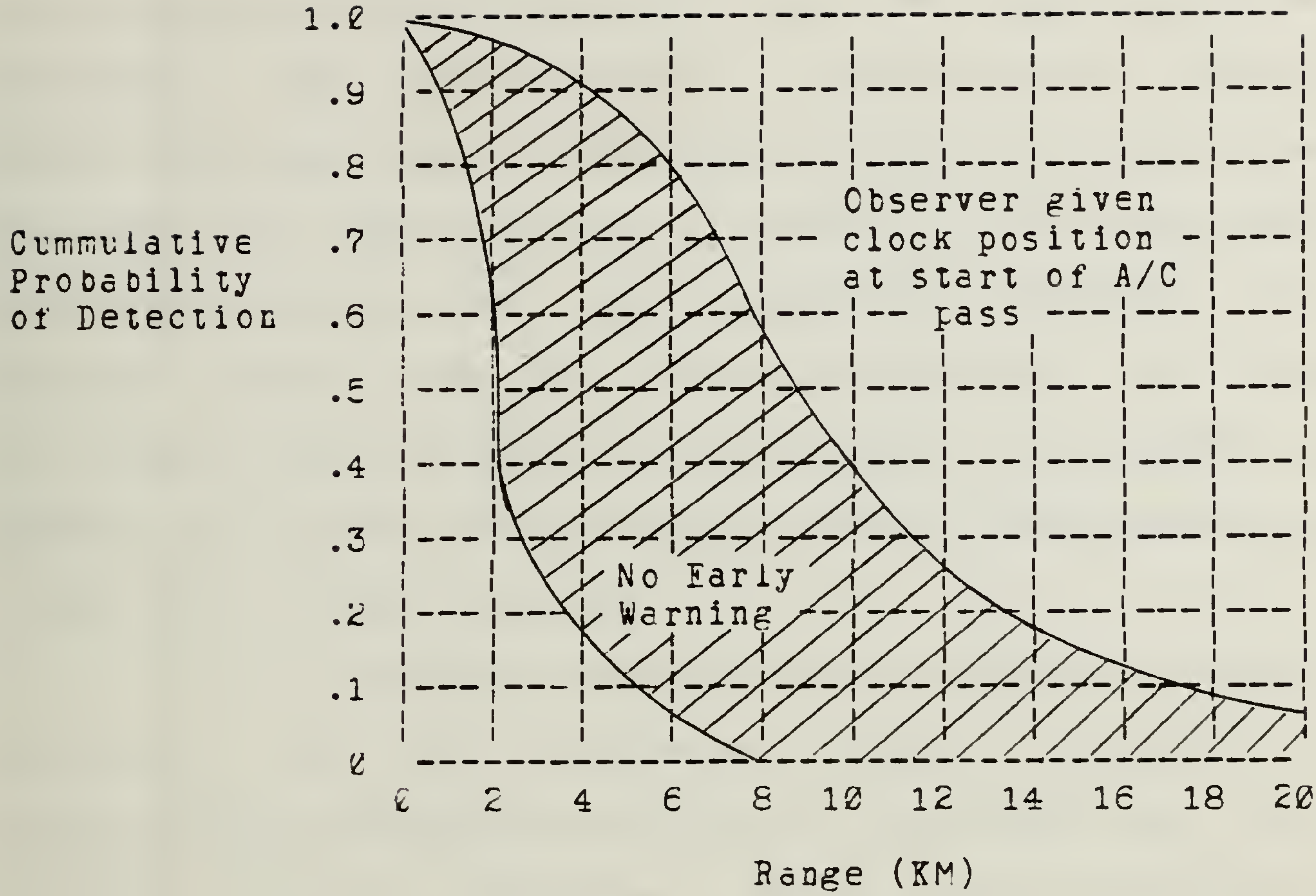


Figure 3. Alerting vs. No-Alerting

a. Current Capability

In operational divisions there are two means of providing early warning to firing units. One system utilizes sensors designed specifically for SHORAD alerting, while the second takes advantage of other sensors in the division area.

(1) <u>Forward Area Alerting Radar--Target Alert Data Display Set (FAAR-TADDS)</u>. FAAR-TADDS was designed to provide early warning consisting of general location and tentative identification of aerial targets that are within 17 kilometers of the radar. There are eight FAAR in the SHORAD battalion (see Figure 2). These radars can be either

centrally controlled or attached. to the Chaparral/Vulcan batteries. The radar shelter is mounted on a 1 1/4 ton cargo truck (gama goat). According to the field manual for emplacing the FAAR system, FM 44-6, it requires 20-30 minutes to set up and begin operations depending upon weather, terrain and the tactical situation. The system uses doppler shift to acquire moving targets at speeds in excess of 40 knots and can detect hovering helicopters due to the rate of blade rotation.

Acquired targets are displayed on a control indicator and are challenged either manually or automatically depending upon mode of operation and unit standard operating procedure. Based on the IFF response, the operator then presses a "friend" or "foe" pushbutton which displays appropriate symbology on the indicator scope and simultaneously transmits the data via radio frequency data link (RFDL) to any potential TADDS users within line of sight and FM transmit/receive range restrictions of that FAAR.

Every firing unit within the division is authorized a TADDS for obtaining early warning data. The TADDS contains an FM receiver and a decoder that processes the RFDL signal from the FAAR. The information is displayed on a 7 by 7 square matrix, where each of the forty-nine squares represent a five kilometer square on the ground. Within each square are two discs: a green disc indicates the

presence of a friendly aircraft over that five square kilometers while an orange disc indicates an unknown aircraft. Both green and orange discs within a square may be displayed at any one time. However, no indication as to the number of aircraft is provided with either disc presentation.

(2) Early Warning Broadcast Net (EWBN). The EWBN is a one-way voice-tell FM net which originates at the division or SHORAD battalion tactical operations center (TOC). The net depends upon the local division structure and is not standard. Its primary purpose is to pass long-range track information to fire units throughout the division. This net will be discussed in greater detail in chapter two, paragraph 3b.

b. Automated Early Warning

HIMAD systems have organic radars with long-range acquisition capabilities and state of the art automated systems to provide early warning, target identification, selection of priority targets, and engagement sequences. This assists in the engagement of targets at the earliest time and may afford reengagement of targets as well as limit occurrences of simultaneous engagement.

Firing doctrine varies with the tactical situation to provide the best mix of firepower and missile conservation. The doctrine of "shoot-look-shoot" provides

[illegible]

[illegible]

[illegible]

[illegible]

for reengagement of targets not destroyed by initial fires. "Ripple fire" is firing a series of missiles from one unit at predetermined intervals between launches without waiting for intercept of prior launches. (System limitations preclude the later firing doctrine for Nike Hercules.)

(1) Application of the Lawson Model. SHORAD weapon systems do not enjoy the luxury of automation for any portion of the engagement sequence. The Lawson model of the command and control process (see Figure 4) provides a reference for examining the SHORAD engagement sequence. [Ref. 3] The model consists of four functions: SENSE, COMPARE, DECIDE, and ACT. Each function relates to the engagement process in the following manner:

o SENSE
Fire unit personnel search the environment for aircraft. The sensing function ends with aircraft detection.

o COMPARE
The fire unit then attempts to determine the aircraft identity by comparison.

o DECIDE

Once identified, the squad/team leader must decide whether or not to engage.

o ACT

The fire unit takes appropriate action, which commences with the squad/team leader's command. (FIRE or HOLD FIRE)

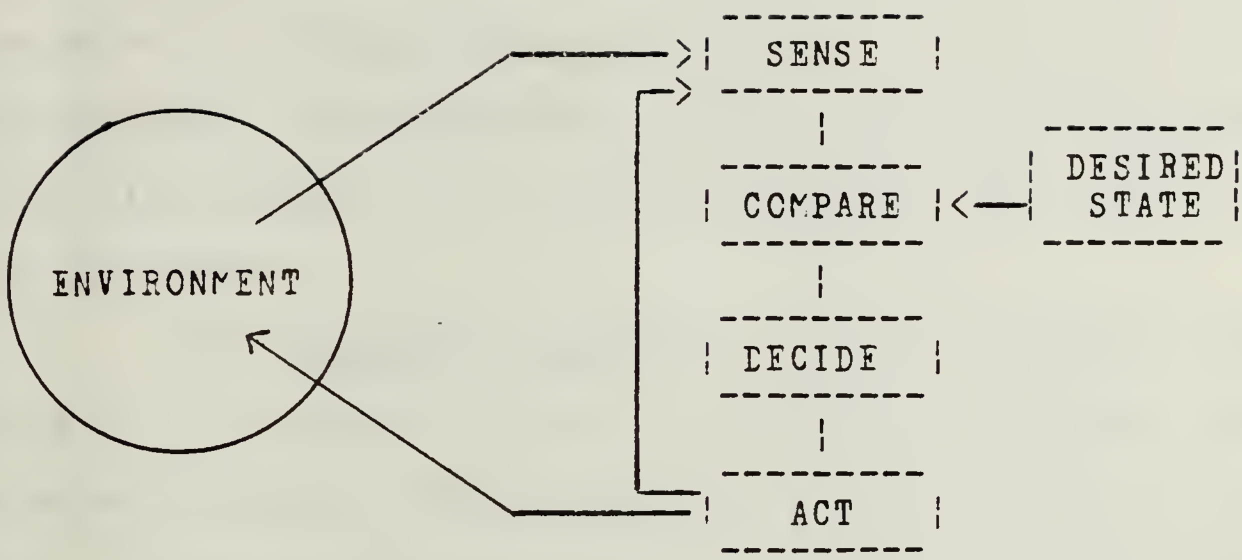


Figure 4. Command and Control Process

Each of the above functions may consist of one or more processes. The processes will be described within the appropriate function title. SENSE Function: The acquisition process is assisted by the FAAR-TADDS system but fire unit personnel must visually acquire the target. COMPARE Function: Once an aircraft has been detected, the squad/team leader must determine if the aircraft is hostile or not. He does this by means of visual aircraft recognition techniques and within the definition of hostile criteria.

> "Hostile criteria includes but is not limited to observing an:
> - Aircraft attacking friendly troops or a defended asset.
> - Aircraft having the markings/configuration of an aircraft belonging to an enemy force." [Ref. 4]

This is the identification phase. DECIDE Function: Once

identified as hostile the squad/team leader decides to engage based on system range capabilities. ACT Function: Having decided to engage the aircraft, the first act is to give the fire command. All subsequent actions are part of the act function.

(2) <u>Engagement Process</u>. The procedures for engaging an aircraft with a Stinger system are representative of all SHORAD systems and will be used as an example. Given the fire command, the gunner must activate the weapon system and "lock-on" the infrared radiation from the target aircraft. The final stage is to superelevate, lead and fire. Lead angle is dependent upon the attitude

```
                     "C"    "D"
                      O      E
                      M      C
                   |  P  |   I  |                         |
<---- "SENSE" ---->|<-A->|<--D->|<-------- "ACT" -------->|
                   |  R  |   E  |                         |
                   |  E  |      |       Activ. S.Elev     |
Sensor Early Visual|     |      | Fire    &      &    Msl.|
Detect Warn. Acquir| ID  |Decide| Cmd.  LockOn  Fire  Away|
------|-----|------|-----|------|-------|------|------|---|->
                                        |               Time
                                        |                 |
         Variable Time Based            |  Fixed System   |
-------- on Individual & C2 ---------->|<- Reaction Time->|
            Assistance                  |                 |
```

Figure 5. Stinger Engagement Process

of the target (head on, crossing, outgoing) while superelevation is required to prevent the missile from

[illegible]

hitting the ground on launch for low flying targets. All of these phases of the engagement process are manually executed and consume a considerable amount of time. Figure 5 portrays the Stinger engagement sequence on a timeline with the command and control process superimposed.

The above described manual engagement system presents a sharp contrast to the highly automated HIMAD systems. The HIMAD systems can also detect targets at long range through their organic radars. SHORAD, on the other hand, has no radars organic to the weapon systems and no automation to assist in the detection or engagement sequence.

		Acquisition Range: LONG	Acquisition Range: SHORT
Total Engagement Time	FAST	Excellent to Excessive (HIMAD)	Acceptable
	SLOW	Acceptable	NOT Acceptable (SHORAD)

Figure 6. Engagement Time vs. Acquistion Range

(3) Time and Distance Approach. Figure 6 depicts a common sense approach to the physical properties of time, speed and distance when associated with air defense systems and aircraft operations. Acquisition range, when applied to SHORAD, is the range from the target to the fire unit when the supporting radar detects the target. Total engagement time in both cases (HIMAD and SHORAD) is the amount of time required from sensor detection of a target to get either a missile or bullets into the air at that particular target. HIMAD systems meet the parameters for the upper left quadrant while SHORAD state of the art falls into the lower right category. No SHORAD-C2 system should exhibit characteristics that allow this to continue. The system must move SHORAD into one of the adjacent quadrants. Obviously, there are three possible ways to better the current SHORAD early warning capability: either increase the acquisition range or decrease the reaction time or both.

Two disadvantages to increasing sensor acquisition range as a sole solution are:

- as radar range (power) increases, they are more easily located by direction finding techniques.
- masking associated with positioning of sensors for low-altitude detection neutralizes the advantage of long-range radars.

The approach to decreasing engagement time, therefore, must be examined. In review of the engagement process depicted in Figure 5, it would be extremely costly to redesign the weapon system in order to decrease the fixed system reaction time. Even then, a new system design would produce very little time savings since system reaction time was a factor in the design of the current systems. However, the time consumed in the sense, compare, and decide functions, with emphasis on sensing, has the potential for substantial reduction. The hypothetical situation that follows may help demonstrate that potential.

Were the FAAR control indicator placed right in front of the Stinger team leader, removing the need for target extraction and transmission by the FAAR operator, there would be a savings of some time. The accuracy of a properly oriented control indicator would improve the visual acquisition time of the team over the gross positional data (5 km square when properly oriented) of the TADDS. Once detected by the team, visual aircraft recognition techniques are required for proper identification of the aircraft before further action can be taken.

This example was given not to suggest the placement of a FAAR at each fire unit but, to demonstrate, in general terms, that the acquisition time can be reduced. That reduction can be accomplished thru the automation of information processing to simulate the real-time presence of

sensor data at the fire unit. The closer to real-time that processing becomes, the less engagement time is consumed.

II. NATURE OF THE PROBLEM

A. THE THREAT

The Soviet Union poses the most sophisticated and numerically significant air threat that the U.S. Army can expect to face. The greatest air threat is in central Europe where there is a capability of some 4000 enemy aircraft. All of these aircraft are expected to exhibit a number of improvements; increased radius of operation, weapons load increases, high performance avionics, sensors designed to improve night and all-weather combat capabilities, more accurate weapons delivery systems and better electronic warfare equipment. [Ref. 5] Though all of these aircraft are not expected to pose a direct threat to SHORAD, it is this type threat that the SHORAD battalion must be prepared to engage and do so in an efficient and effective manner. There are four basic air threat missions to consider when designing an air defense system for the division. These will be addressed in order of increasing threat to the division.

1. Close Air Support

The threat envisioned two air battles occurring within divisional airspace. The forward air battle would consist primarily of helicopters attacking ground maneuver forces. The second air battle would be waged in the

[illegible]

division rear area where fixed-wing close air support (CAS) aircraft would attack critical assets. [Ref. 6] The advent of the larger numbers of Soviet Hind and Hip helicopters with great firepower and anti-tank capability has changed the complexion of the forces needed to protect the division against the low-altitude air threat. These heavily armed helicopters have assumed the primary role of supporting ground forces in the main battle along the forward edge of the battle area (FEBA), an area that had previously not been supported.

2. Reconnaissance

Another significant air threat the division must combat is reconnaissance missions. These aircraft can be either remotely piloted vehicles (RPV) or manned fixed-wing aircraft and are usually characterized by using low altitude and high speeds to gather intelligence. The RPV may be used for gathering near-real time identification and location information to support artillery and/or CAS missions and presents a serious threat to the division because of its small size and ability to penetrate "high risk" areas that may be considered well defended. [Ref. 7]

3. Interdiction

The last category of air threat posed directly at the division and echelons above division is interdiction. This mission is aimed against ground forces and logistics from the division rear to the rear of the army groups. This

mission is typically carried out by manned fighter bombers that may have the capability of low-level penetration to attack rear area targets.

4. Offensive Counter Air

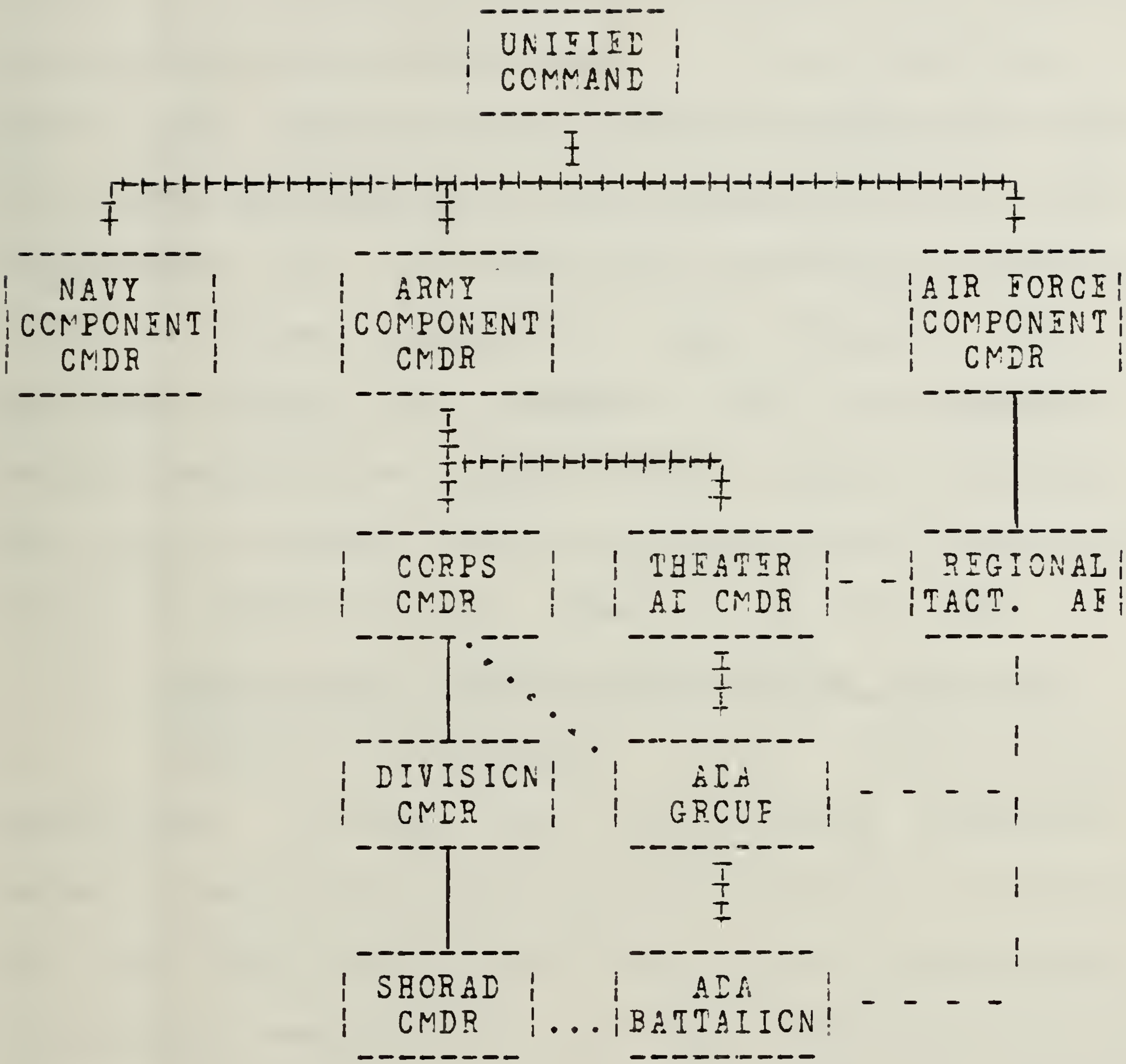
Offensive counter air missions are directed at airfields, logistics facilities supporting air operations and airspace surveillance and direction systems. [Ref. 8] Since most airfields in the corps and division rear do not contribute directly to the air superiority role, the targets for enemy offensive counter air will be well to the rear of the division. Therefore, enemy aircraft assigned the mission of offensive counter air may overfly one or more divisions at low altitude enroute to rear area targets.

B. SHORAD-C2 TODAY

This thesis will focus on the information flow required to maximize air defense effectiveness once deployed and not dwell on the C2 aspects of air defense employment/maneuver and the associated tactics.

1. U.S. Air Force Control

The SHORAD systems within the division do not operate autonomously. There is a definitive command and operational control line under which all air defense artillery (ADA) units operate. This line begins with the area air defense commander and is shown at Figure 7.



——— Command (-+++ less Operational Control)
- - - Operational Control
..... Coordination

Figure 7: Organization For Theater Air Battle Management

The area air defense commander, normally the Air Force component commander, divides the theater into regions for air defense purposes. The region air defense commander, normally the tactical air force commander, is responsible

for, and has full authority in, the air defense of his region. He normally delegates authority for employment of organic Army air defense means to the commanders of the major Army elements (ie. divisions) within his region. He will normally delegate to the commanders of the major Army subdivisions of his region the authority to move Army ADA units in direct support of army forces. The region commander issues air defense rules of engagement, air defense warnings and weapons control status (see Table II), but this is normally the only theater level control over the firing of SHORAD weapons. [Ref. 9: pp. 5-2, 5-3]

2. Centralized Control/Decentralized Execution

SHORAD-C2 procedures are characterized by centralized control and decentralized execution. Air defense alerting and controlling information is developed by the Air Force for each region and locally within each division at headquarters that are adequately staffed to collect, process, evaluate and disseminate relevant air defense intelligence information. Conversely, SHORAD weapons are manned and fired by squads/teams which are separated from all other members of the same defense. Therefore, to be effective, the firing decision must be made at the weapon systems and authority to engage must be delegated to the firing team commanders.

Decentralized execution of division air defense by small remote teams poses a tremendous challenge to the

SHORAD battalion commander who exercises command over all ADA units organic, assigned or attached to the division. To meet the C2 need, several control procedures exist within ADA units to preclude SHORAD engagement of friendly aircraft. These control procedures consist of rules of engagement, weapons control status and air defense warnings (see Table II). Procedures are not necessarily standard in divisions throughout the Army.

TABLE II

CONTROL PROCEDURES

o RULES OF ENGAGEMENT
  * Hostile Criteria
    - Attacking friendly forces or assets
    - Markings/configurations of enemy A/C
  * Weapons Control Status

o WEAPONS CONTROL STATUS
  * Weapons Free - fire at any A/C not positively identified as friendly
  * Weapons Tight - fire only at A/C positively identified as hostile according to hostile criteria
  * Weapons Hold - fire in self-defense only

o AIR DEFENSE WARNINGS
  * Red - Attack is eminent or in progress
  * Yellow - Attack is probable
  * White - Attack not probable

[Ref. 9: pp. 5-8, 5-11]

3. Dissemination of Control Procedures/Early Warning

High to medium altitude air defense (HIMAD) systems in or near the division area operate with an electronic command and control system, AN/TSQ-73 Missile Minder, that

has data link communications with the Air Force regional control system, enabling the exchange of aircraft track information and direct air defense control procedures. Since IHAWK is expected to be employed either in direct support (DS) or general support (GS) of the division, this information can be disseminated to pertinent users by establishing a link between the HIMAD (IHAWK) unit and the SHORAD battalion TCC. If no HIMAD systems are in or near the division the link must be to the Air Force forward air control post (FACP), control and reporting center (CRC) or control and reporting post (CRP). The link to the region air defense commander is critical and must be established either directly or indirectly to pass air defense C2 information.

a. Air Defense Coordination Net (ADCN)

Change two to the "ADA Employment, Chaparral/Vulcan" field manual added an appendix to provide Army wide standardization and to definitively explain the procedures and resources required to establish the link mentioned above. It describes (as shown at Figure 8) the air defense coordination net (ADCN) by which the air defense coordination section (ADCS) disseminate both track data and control information to the SHORAD TCC.

The air defense coordination officer (ADCO) has an AN/GRC-106 AM radio for the long range communication requirement as well as two additional personnel to maintain

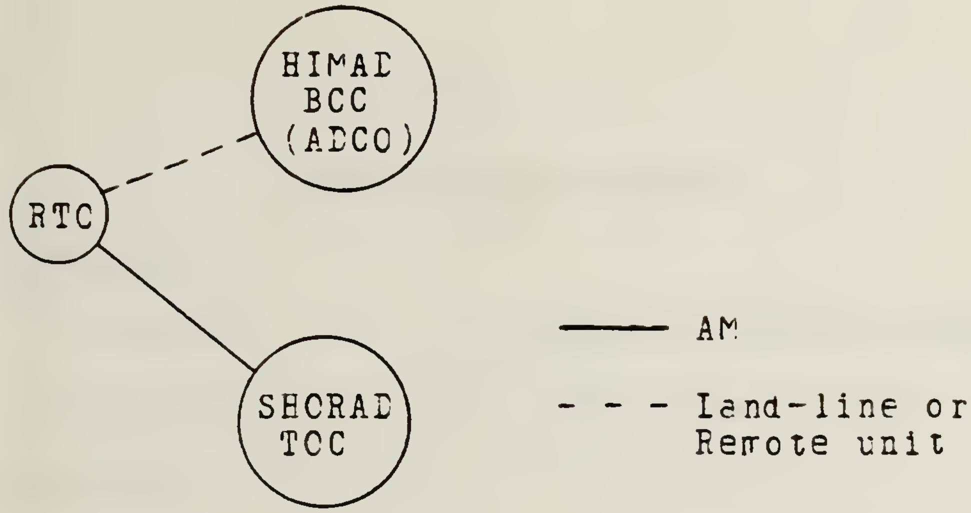


Figure 8. Air Defense Coordination Net

continuous operations. The control procedure information is sent to the SHORAD TOC only when there is a change in status, while track positions are transmitted as the track data becomes available. The ADCO obtains HIMAD track information by physically viewing the radar console. He may initiate the report from inside the source van if he is equipped with a remote unit. If not, he must call via land line to the driver/RTO who transmits the report on the radio.

For track reports, the location (using a SHORAD grid system) and raid size must always be sent while heading, identification and aircraft type need only be sent when time permits. (see Table III) Update information is not reported until the track moves into another 10 kilometer grid designator, at which time it is rebroadcast in total. (Some of the obvious flaws in this system will be discussed at length later in this chapter.)

TABLE III

TRACK REPORT FORMAT

MANDATORY	
Location	Orange (10 km grid designator)
Raid Size	One, Few (2-4), Many
OPTIONAL	
ID	Unknown, Hostile
Heading	Southwest, North, etc.
Type	Jet, Helo, Prop.

[Ref. 9: p. I-6]

b. Early Warning Broadcast Net (EWBN)

At the SHORAD TCC personnel receive the ADCC's reports on their AN/GRC-106A radio and:

o record the tracks.

o determine if the track requires retransmission.

o transmit appropriate early warning over the early warning broadcast net (EWBN).

o transmit air defense warnings over the EWBN and transmit other air defense C2 information over the battalion command net.

The early warning broadcast net (EWBN) provides long-range early warning and control procedure information to any unit with an FM receiver and within line of sight (LOS) and operating range of the SHORAD TCC. FAAR operators are required to monitor the EWBN by using the AN/VRC-46 radio

normally used for their platoon command net. The operator then voice-tells the information received from the SHORAD TOC in addition to sending those tracks detected by his own radar system either by voice or RFDL. (see Figure 9)

This relay of EWBN information can potentially double the range and multiply the coverage by eight (number of FAARs) over that that the one originating transmitter had. It also provides for better coverage of dead spots, since the FAAR are normally positioned on higher ground, while the TOC would be in a more secure and lower position which offers poor ICS coverage. (Again, the weaknesses in this system will be addressed in section C1a.)

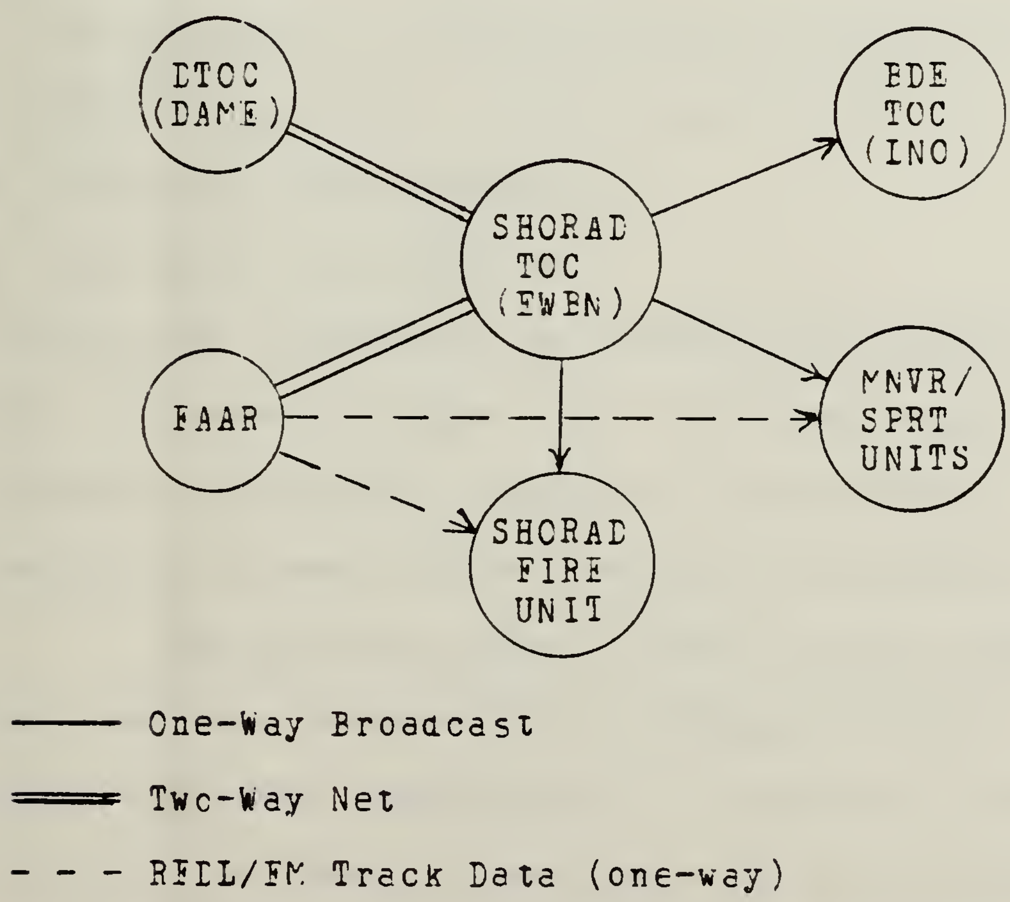


Figure 9: Early Warning Broadcast Net

4. <u>Division Airspace Management Element (DAME)</u>

Having described the procedures and networks for getting C2 information relayed from the regional air defense commander to the fire unit, it is necessary to address one final and key node in the SHORAD-C2 system: the division. The focal point for coordination of AD operations within the division area occur at the division main TOC (DTOC) and the tactical command post (TAC CP). The division airspace management element (DAME) is an integral part of the DTOC and consists of SHORAD and army aviation personnel. (An ADA element in the TAC CP performs similar functions.) The DAME to SHORAD TOC link has several potential means of communications:

o Multi-channel (installed by the signal bn.)

o AM/SSB operations & intelligence (RATT)

o FM command net (SHORAD bn.)

o Land Line (if feasible)

Maintaining communications between the DAME and the SHORAD TOC is crucial since the Air Force liason officer (ALO), located in the DTOC, provides a second means of obtaining or verifying current control procedure information.

The DAME has better access to the maneuver brigades and the air defense liason officers (LNOs) in each brigade TOC. The DAME, therefore, is able to maintain a good "picture" of what is occuring both on the ground and in the air. DAME communications with the brigade LNOs completes

the loop (see Figure 10) since the Chaparral/Vulcan batteries coordinate with the appropriate brigade thru the LNO. (If there is no battery operating in a particular brigade area the LNO would be in direct contact with the SHORAD battalion.) The coordination with the LNO typically utilizes FM radios, however, land line may be installed depending upon the situation.

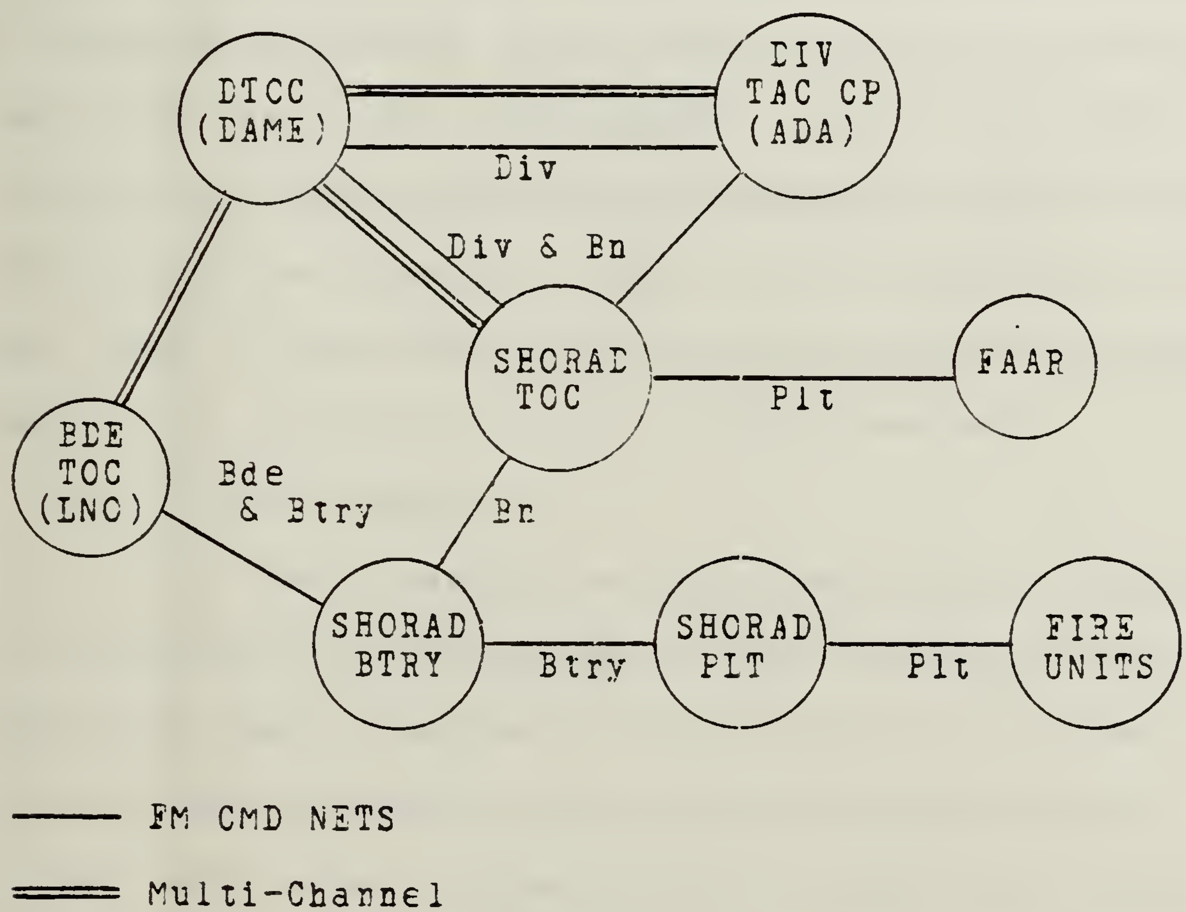


Figure 10: AD Communications within the Division

C. SHORAD-C2 DEFICIENCIES

1. Early Warning/Control Procedures

REFORGER after action reports since 1975 have continually stated that current early warning systems do not meet Army requirements. Some of the arguements against and weaknesses of the system in the field today are serious.

a. One-way Communication

Given that the EWBN is a one-way network, as are track data transmissions from the FAAR to fire units, it is a certainty that some voice traffic will not be received by the FAAR operators and relayed. Also, some traffic either direct or relayed will not be received by the fire units for one of several reasons. Even with an optimistic assumption that 100% of the track data reaches all 115 fire units, the data is so "old" that it is virtually useless.

b. No Cueing

Early warning as described thus far has amounted to alerting only. Alerting is the portion of early warning where the user is warned that an aircraft is in the area of interest which requires only gross positional data. Cueing, on the other hand, is the process of providing information to the fire units which tells him where to look for a target and provides him with tentative identification of that target. The Air Defense Center at Ft. Bliss, Tx. uses the criterion that cueing must be accurate to within plus or minus ten degrees of the true azimuth to the target and to

within three seconds of the target's detected location. Neither FAAR-TADDS nor the MSCS system provide cueing to SHORAD fire units.

c. FAAR-TADDS Shortcomings

At the heart of SHORAD early warning is the FAAR-TADDS system which has been plagued with operational and maintenance problems since first fielding over a decade ago. Some identified problem areas with the radar are:

o Manual target extraction.

o Vehicle turnovers.

o High failure rate of some parts.

o Low capability in an ECM environment.

o Lack of radar range coverage.

(1) No Network of Sensors. An apparent deficiency is the lack of a network, such that a fire unit is dependant on one source of early warning. This compounds the squad/team leader's problem should the FAAR from which he is receiving track data become non-operational due to equipment failure, being directed to move or not move to keep up with the movement of the fire unit.

(2) Mobility/Deployment Restrictions. Deployment guidelines for FAAR-TADDS take into consideration the system's capabilities and limitations. These include deploying FAAR no closer than two kilometers from the FEBA for security reasons. Ideally the FAAR should be positioned no more than nine kilometers apart to maintain continuous

radar coverage should one system become non-operational or be directed to move. To provide "adequate" alerting to the fire units, radar coverage should extend at least ten kilometers beyond the supported units. These guidelines would force the FAAR to either prepare to move, move or prepare for emplacement nearly as often as it would be in position and operational for any dynamic type situation in support of maneuver forces. Missions of this type can be expected to occur 50% of the time as was shown at Table I of chapter I. It's during just such a dynamic scenario that "good" early warning is needed the most. A system that is operational only 50-75% of the time is unacceptable to the fire units in question.

A very experienced squad/team leader may be able to keep up with the many radar status changes were he sitting in a static defensive posture. However, the same dynamic situation that might cause the FAAR to move frequently will most certainly force many more moves on the weapon systems. For the TADDS to display usable target information at the fire unit, the following requirements must be met:

o the squad/team leader must know the location of the FAAR from which he is receiving data.

o the FAAR and TADDS must be oriented in the same direction.

o the TADDS must be set on the same FM frequency and RFIL address code as the associated FAAR.

o the fire unit must be within 15 km of the FAAR.

o the FAAR/TADDS must maintain LOS. [Ref. 10]

Assuming the squad/team leader has the necessary information on at least three of the FAAR that will be operating nearest to his particular area of operation, it is very likely that the required information would have changed several times during the course of a day and be invalid when needed. The FAAR location is needed because the TADDS is oriented with the FAAR positioned in the center. The fire unit is manually plotted on the TADDS by the squad/team leader requiring a new plot with every FAAR and/or fire unit move.

The potential for error in location, address code and orientation is great. Much time and effort by command personnel and over command nets has been spent during exercises to try and correct problems resulting from operator error, misunderstandings and poor preparation. Typically, the Stinger teams are the most difficult to contact and are often not informed of FAAR moves. Often dissatisfaction with the FAAR-TADDS system results in squads/teams depending solely on visual acquisition by one of the section or team members. Again, an unacceptable situation.

a. Long Range Track Data

The problems mentioned above led to widespread development of varying types of early warning and manual plotting systems. In January 1982 a change to FM 44-3 was published to standardize a manual SHORAD control system (MSCS) consisting of the ADCN and EWBN which were were described earlier. The intent was not so much to do away with FAAR-TADDS deficiencies (though a grid system was introduced to allow for manual passing of track data) but, to add long-range track data to the system.

There are, however, as many if not more problems with the long-range track data system. The ADCO initiating the report is either looking over someone's shoulder at a HIMAD scope or looking at a manual plotting board. He then converts, using a board with two overlays, from GEOREF to the SHORAD grid. He then may have to relay the report to his RTO who transmits it to the SHORAD TOC. Processing at the TOC may determine that it needs to be broadcast over the EWBN. For those fire units not within FM reception of the SHORAD TOC, a relay by the FAAR operator finally gets the track data to the fire unit. As many as five retransmissions for a single track report!

In addition to the delay associated with numerous retransmission, there is the problem of confusion. The ADCO, who is looking over a console in the battery control center (BCC) van, is typically in the way of IHAWK

operations and, therefore, the first to be forced out when the situation gets intense. His reporting process (land-line or remote unit) becomes distracting to the IHAWK mission.

At the SHORAD TOC the confusion level increases as FAAR and ADCC reports flood the system. The manual plotting and rebroadcasting functions can easily become unworkable with moderate to heavy air traffic. (There are eight receivers from FAAR and one from the ADCC "squawking" reports.)

With no feedback loop from the fire units to the EWBN, there is no means for managing the system problems. The confusion on the part of the fire units during periods of heavy air attack will only be increased by the receipt of excited and confusing reports over the EWBN. The manual SHORAD control system (MSCS) is unworkable.

2. <u>Airspace Management</u>

Despite an obvious need for an airspace management system forward of the division rear, there is no common system in the Army today. FM 1-60, Airspace Management and Army Air Traffic in a Combat Zone, provides Army doctrine for airspace control and airspace management, but this field manual has vague requirements that lack the methodology and division structure necessary for implementation. For these and other reasons, airspace management is in need of a more refined definition, a process that is ongoing.

Air defense artillery is a key information source to airspace management and at the same time dependant upon other inputs, particularly the Army aviation. The link between these two important airspace users is a critical one performed by the DAME in the DTOC. Without further refinement of the responsibilities for airspace management (though needed and under study), there are several areas where SHORAD-C2 is lacking in support of current airspace management.

To manage the division airspace properly, a near real-time system for exchange, process and display of C2 information is needed. That system does not exist today. Without such a system it is extremely difficult to conduct any semi-complex scenario involving several changes to warning conditions, weapons control statuses, mission definition, friendly/enemy electronic countermeasure activity, sensor management or unit locations and status effectively. Execution of such a system requires a two-way dialog because some information is needed at the fire units while other is needed at the SHORAD TOC and the DAME. An acknowledgement is normally desired as well. Both of these factors contribute to an excessive amount of radio time on command channels.

Typically, the timeliness of unit locations and status at the DTOC will be in excess of one hour due to retransmissions and other radio traffic requirements. In

the dynamic environment of the air battle, changes are current for only seconds, possibly minutes, but not hours. A delay of this sort does not keep the DAME current on the air defense "picture". Likewise, changes in weapon control status, mission assignments and new sensor locations can take excessive amounts of time to reach each fire unit. Again, with 115 fire units there will always be some that will be operating with old/invalid C2 information which will render them useless or a threat to friendly aircraft.

This lack of a near real time SHORAD-C2 system has precluded effective use of the division airspace. At the same time, the SHORAD-C2 deficiencies have created a stigma in which both Air Force pilots and commanders perceive Army air defense as a real threat. Past experience has shown that when Air Force aircraft penetrate division airspace at low altitudes, the region air defense commander has restricted the weapons control status for an entire division area or more well in advance of that mission to afford the maximum protection from Army air defense. This unfortunate reality has decreased air defense effectiveness over a much larger area and for a longer period of time than necessary.

D. THE NEED

The areas described above indicate a need for an improvement to current SHORAD-C2. Several studies have been conducted to determine the value of cueing and other C2

aspects of SHORAD. One such study by the Army Materiel Systems Analysis Activity (AMSAA) titled "Division Air Defense Command and Control" (DADC2) showed that automation using the AN/TSQ-73 Missile Minder, an automated FAAR, a transmission scheme translator, and a hand-held terminal display resulted in 100% increase in hostile aircraft kills, 70% decrease in damage to friendly assets and up to 500% increase in air defense effectiveness.

With technology available today, automation of some of the C2 functions can provide:

1. timely and accurate cueing data to the fire team. (elimination of manual delay, errors and saturation)
2. improved system operation and survivability. (EMCON, radar blinking)
3. reduction in size and configuration to enhance deployability/mobility. (no need for plotting boards and plotters)
4. real-time dissemination and receipt of division air battle information.
5. maximum firepower against enemy, while protecting friendly aircraft.
6. operate effectively in a sophisticated electronic warfare environment.

The gap between system capabilities today and the requirements for a SHORAD-C2 system necessitate development of an automated system. Though this fact is generally

agreed upon by the air defense community there is wide disagreement over the composition of the system to do the job.

III. BASELINE METHODOLOGY

The methodology used to conduct a comparative analysis includes definition of the environment in which the new command and control system will operate. That environment consists of the division as it will be fielded in 1986 and the SHORAD battalion in that timeframe. The operational requirements for a SHORAD-C2 system will be defined in terms of constraints and criteria. This system definition will act as a framework to be used as a comparative basis for the two proposed systems: one by Sanders and one by Litton.

A. THE DIVISION IN 1986

There are five type divisions in the Army today. The type divisions span a variety of missions and mobility requirements to enable the land forces to operate in nearly all environmental conditions worldwide. Rather than address all five types, the heavy division will serve as the basis for further discussion. The choice of the heavy division was motivated by the number of heavy divisions currently in the Army and by available data on the Division 86 structure for the heavy division. The division structure, less air defense, is described in brief at Appendix B.

B. DIVISION 86 AIR DEFENSE

1. Organization

The division in 1986, as described at Appendix B, is manned and equipped to the capacity deemed necessary and acceptable by the Commanding General of the Training and Doctrine Command (TRADOC). This proposed force structure was subsequently approved by the Chief of Staff of the Army. Modifications have and probably will continue to be made to that structure, but the basic elements requiring air defense protection will remain intact. It will, therefore, pose a tremendous challenge to the division air defense officer to provide protection from aerial attack to the many and varied critical assets within the Division 86 structure.

The sheer number of critical assets requiring air defense coverage far outnumber the air defense resources. This fact requires that the division commander specify certain assets as priorities for air defense. Past experience has shown that certain assets are normally designated as priorities and they include: the maneuver brigades, the DISCOM, the nuclear capable FA, the DTOC and the division TACTICAL CP.

The maneuver brigades are well forward and in contact with the enemy which requires supporting air defense units be both as survivable and mobile as the units they are supporting. The other air defense priorities are generally less mobile and are considered fixed assets. These facts

[illegible]

contributed to the development of the division 86 air defense organization and will directly affect the design and capabilities of early warning equipment.

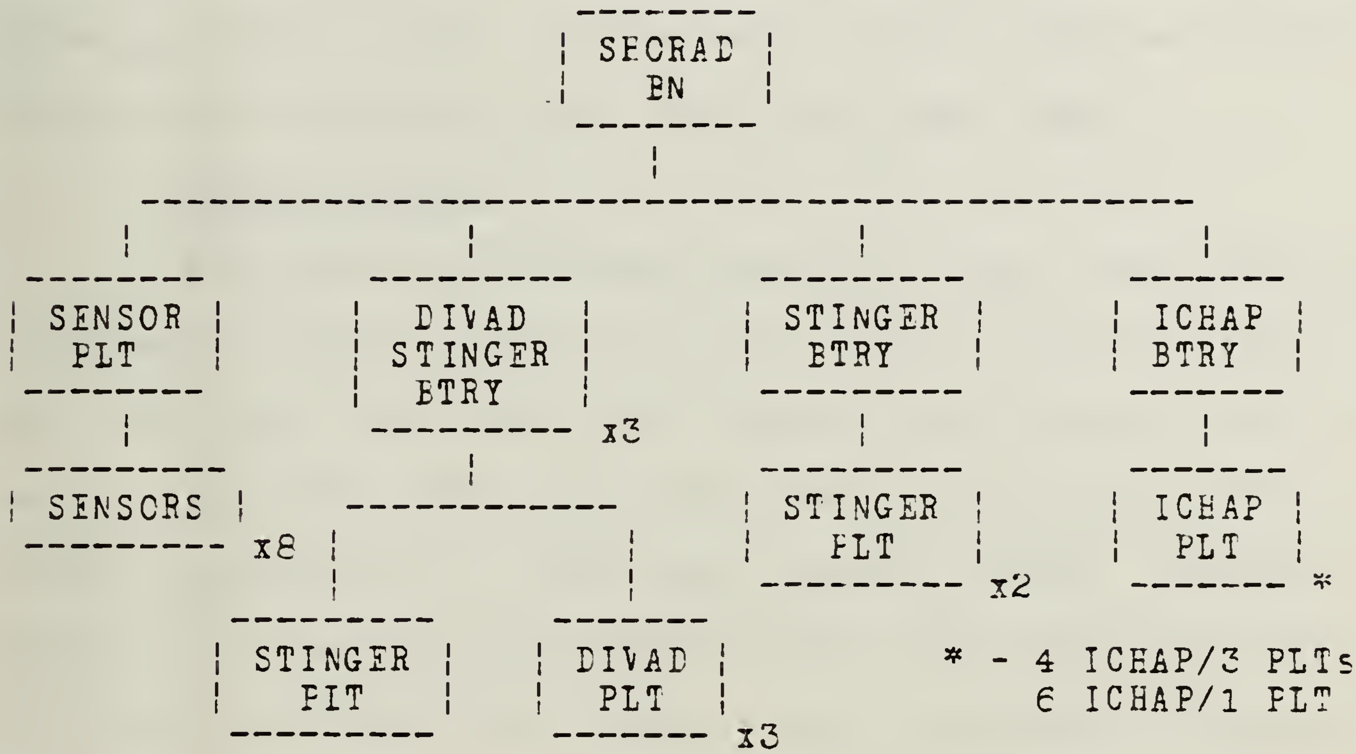


Figure 11. Division 86 Air Defense Battalion

As of January 1983, the SHORAD-C2 office of the Directorate of Combat Development (DCD) at Ft. Bliss, Tx. has stated that the heavy division will be equipped with 36 division air defense (DIVAD) guns, 18 improved Chaparrals (ICHAP), and 75 Stinger (MANPADS) teams. (This has not changed since the SHORAD Command and Control (C2) Operational and Organizational (O and O) Concept of 22 November 1982 was prepared.) The organization depicted at Figure 11 provides each maneuver brigade with a

DIVAD/MANPADS battery and an ICHAP battery and Stinger battery for rear area fixed asset defense. This organization was developed to support the concept that the SHORAD battalion would be engaged in two air battles: one, primarily helicopter, forward and over the maneuver forces; the second, primarily fixed wing, over rear areas.

2. <u>Weapon Systems</u>

The Division 86 SHORAD battalion will realize the firepower increase, mobility, survivability, and accuracy of the DIVAD gun. The DIVAD will replace the vulcan (in the heavy division) and will join the improved Chaparral and Stinger systems in a new and larger SHORAD battalion. Because of the size and weight of the tank chassis on which the gun is mounted, the airborne and airmobile divisions will not be equipped with the DIVAD but, will keep the towed vulcan until a light air defense system (LADS) is fielded to provide the flexibility of air-transportability by both fixed wing aircraft and helicopters.

C. SHORAD-C2 OPERATIONAL REQUIREMENTS

Having described the deficiencies and problem areas in the current SHORAD-C2 system (Chapter II), one's appreciation for the need for a "better" near-real time system leads to the development of operational requirements. The "user", U.S. Army Air Defense School (USAADS) at Ft. Bliss, Tx., formalized their requirements in a June 1982

"Draft LOA (letter of agreement) for a Short-Range Air Defense Command and Control (SHORAD-C2) System". The letter was sent to the U.S. Army Training and Doctrine Command (TRADOC) for approval. The requirements in that letter were delineated as follows:

> "(1) The SHORAD-C2 system will provide an automated assist in accomplishment of the following functions:
> (a) Alerting to SHORAD and supported forces of pending air attack...
> (b) Rapid dissemination and acknowledge of the receipt of selected items of Air Defense Artillery weapons control information.
> (c) Cueing of SHORAD fire units to aircraft in their vicinity...
> (2) The SHORAD system must provide for simple system interface, remote operation of components, mobility and survivability commensurate with supported systems, modular system design, post-development software considerations, use of existing power and communications equipment, safe operations and a multi-modal sensor system." [Ref. 1: pp. 1,2]

These requirements, with amplification and specific constraints and criteria, will act as the cornerstone on which a "baseline" system will be designed for use in the evaluation effort.

Designated a major project, the SHORAD-C2 system is being formally defined in a request for proposal (RFP) that has not yet been completed by the project managers office. The requirements used in this analysis, were developed from the letter of agreement discussed in Chapter II and from the experience and knowledge of SHORAD and command and control by the author. The system requirements are further refined into constraints and criteria listed below.

1. Constraints

There are three basic requirement categories into which each constraint may be placed: performance, fielding, or physical requirements. The constraints that follow are grouped in this manner for continuity purposes.

a. Performance Requirements

- o consolidate sensor information and/or network sensors together
- o provide alerting to fire units
- o provide cueing to fire units
- o provide air battle "picture" and fire unit status to the DAME, Bde TOC, and SHORAD TOC
- o provide command and control information required by fire unit to engage aircraft
- o provide capability to acknowledge receipt of C2 information by fire unit
- o integrate with the DIVAD sensor
- o integrate with HIMAD sensor(s)

b. Fielding Requirements

- o be capable of worldwide operations
- o be capable of fielding in '85-'86 timeframe
- o be compatible with current VRC 12 series radios and the new HF radios as well as the associated secure equipment
- o be compatible with varied division organizations

c. Physical Requirements

- o be equipped with light weight display at the fire unit
- o have a display that is powered by standard batteries/power source
- o have an easy to operate display
- o have highly mobile sensors
- o. be as survivable as supported units
- o be transportable by road, rail, sea and air.

2. <u>Criteria</u>

Each constraint above will have one or more criteria to provide clarification. Justification for the criteria is provided in Appendix A.

a. Performance Requirements

- o A fire unit cannot be dependent upon only one sensor. Each fire unit must have a consolidated "picture" of local airspace from two or more sensors.
- o The fire unit must be provided with at least a 15 km alerting radius.
- o Cueing to the fire unit must be within +/- 10 degree accuracy and 3 second timeliness.
- o The air-battle "picture" on TOC displays must include fire unit status, record of previous track data, and integration of EIMAD/Air Force sensor data.

- The following information by the system to each fire unit to allow aircraft engagement: primary target sector/line, air defense warning, state of alert, weapon control status and tentative identification of tracks.
- The system must provide a means to acknowledge receipt of control procedure information by the fire unit.
- Target track and command data must be compatible with the DIVAD system to allow exchange of data to the DIVAD and from it to the SHORAD-C2 system.
- Long-range track data must be integrated into the SHORAD-C2 system for alerting.

b. Fielding Requirements

- The SHORAD-C2 system must meet environmental and operational testing requirements for worldwide use. Degradation of system capabilities must be consistent with other tactical data systems deployed in the same locale.
- The system can be fielded by '85-'86 timeframe.
- The system either is or is not compatible with the current and new radios and their

associated secure equipment.

o The SHORAD-C2 system must be able to perform its mission with an equal degree of success in four of the five type divisions. It must be able to operate in all five, allowing one division type to be less "successful".

c. Physical Requirements

o The fire unit display cannot exceed 10 pounds nor be larger than a standard briefcase (including batteries and/or cabling to power source).

o Displays at the fire unit must be either powered by standard Army batteries or provide slaving system off weapon or vehicle system.

o The display must be weapon centered and posses an easily learned (by fire unit personnel) man-machine interface.

o The sensor must be as mobile as the supported units (tracks/wheels).

o The sensor must be as survivable as the air defense assets it is supporting. System components at the TCCs/fire units must be as survivable as that TCC/fire unit respectively.

o All system components must be deployable on C-130 aircraft.

IV. SYSTEM DESCRIPTIONS

Sanders and Litton are no strangers to the problems and requirements of Army Air Defense. Each company has been involved with SHORAD and/or other aspects of air defense for some time.

Sanders designed and developed the FAAR that was deployed in 1972. Since that time they have demonstrated to both the U.S. and Isreal certain improvements and modifications to the basic FAAR/TADDS. In 1975, Isreal bought the low altitude aircraft detection system (LAADS) and in 1980 they purchased the improved LAADS from Sanders. [Ref. 11]

Litton Data Systems integrated operational system software for the AN/TSQ-73, Missile Minder, and the tactical fire direction system (TACFIRE). The AN/TSQ-73 is an air defense command and control center for integration of manned interceptor control and surface-to-air missile fire distribution. TACFIRE automates critical field artillery functions.

The Marine Corps contracted Litton to develop a tactical air operations central 1985 (TAOC-85) which is a command and control system capable of coordinating an array of air defense weapons. Litton also completed a study defining minor changes required to adopt the TAOC-85 to the Air

Force. [Ref. 12: p. 1] Additionally, Litton has developed a family of intelligent terminals which transmit data digitally and display it graphically or alphanumerically.

A. SANDERS PROPOSAL

1. Overview

Sanders has not designed a complete package or system to meet all of the SHORAD-C2 requirements. The official requirements document has not been released and rather than guess at the requirements Sanders opted to continue the design and improvement upon a system they already had, the FAAR/TADDS.

The system description that follows is based on demonstrated and "proclaimed" capabilities. The proclaimed capabilities range from those conducted in house by Sanders to a theoretical possibility based on current hardware with minimal software changes.

Some of the components to the C2 system have been proposed by Sanders personnel, MICOM personnel, and air defense personnel from the air defense center at Ft. Bliss, Tx. and in the high technology test bed (HTTB), however, the total system together has been developed by the author. Though the SHORAD-C2 system needs to be considered as a whole, it will be described in two parts: those areas external to the SHORAD battalion and those within the battalion (see Figure 12).

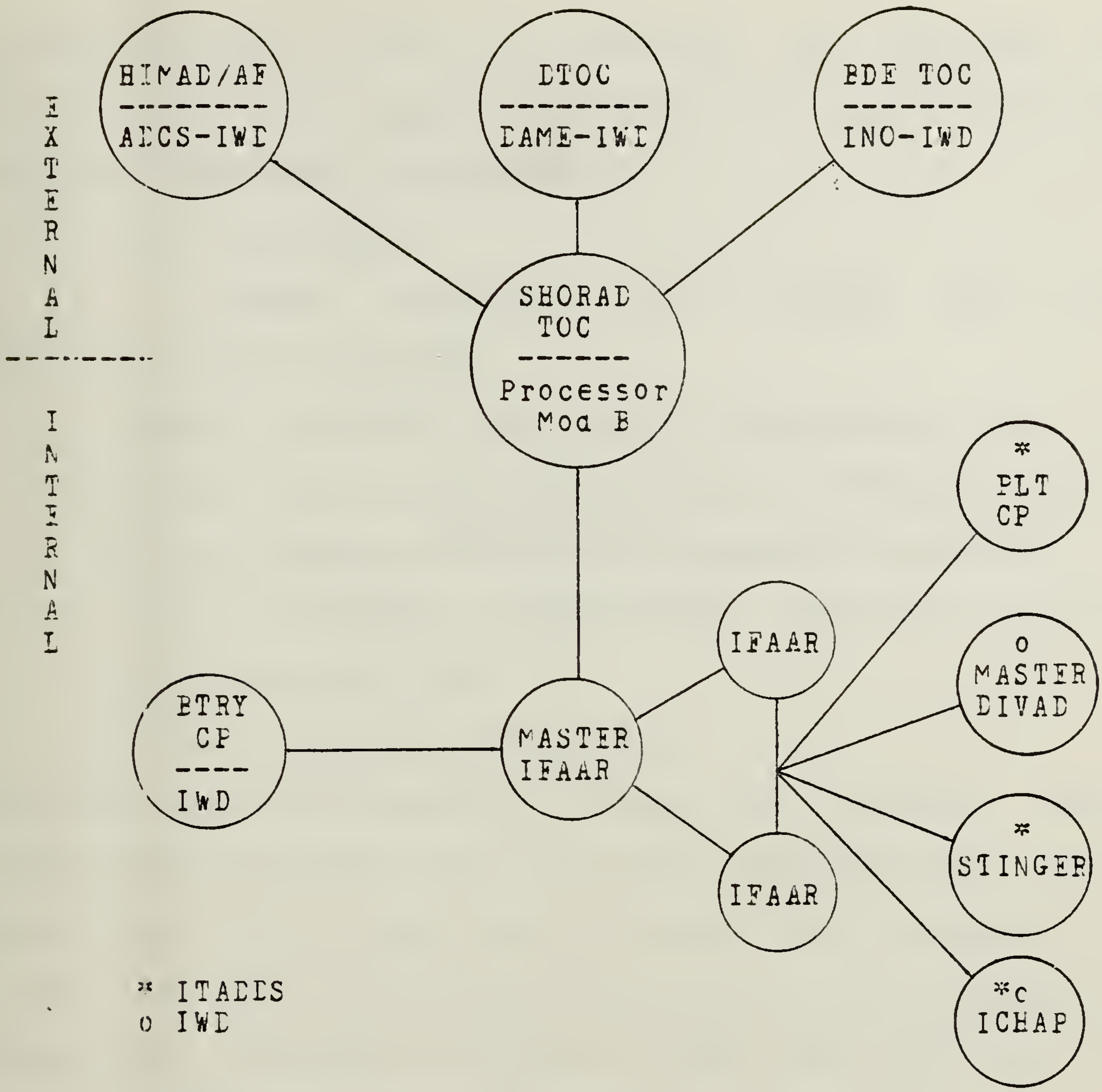


Figure 12. Sanders SHORAD-C2 System Design

2. Internal

Sanders has concentrated their efforts in the area of local early warning through the use of the FAAR and subsequently have developed a system that is primarily internal to the SHORAD battalion. They set out to correct the deficiencies (discussed in chapter II) of the basic FAAR/TADDS system by modifications and improvements

(described below) as well as developing new equipment to meet certain air defense requirements not addressed by the improved FAAR/TADDS (IFAAR/ITADDS).

a. Mod A FAAR

Sanders developed a Mod A FAAR with the following design approach:

- o upgrade standard FAAR with modification kit to automate data processing function to eliminate errors and time delays resulting from operator saturation.
- o data link message to define target position in true map coordinates (UTM)
- o provide for netting radar data.

The above approach resulted in adding an automatic radar information processor (RIP) and a data management unit (DMU) to the basic FAAR. The control indicator was modified to accept the RIP and DMU and to provide a full alphanumeric capability. More radio receivers (R-442) were required and added to complete the Mod A. [Ref. 11]

The DMU provides the capability to receive data from two remote sources, combine those data with the local sensor data, and then retransmit a combined radar picture. This combining capability allows radars to be linked together in a daisy-chain fashion (see Figure 13). The chain provides gradual degradation as the elimination of one radar requires only tuning one R-442 receiver to the next closest radar. It also means that fire units (FU) receive

combined coverage to fill in terrain or electronic counter measures (ECM) gaps of the local radar. The combined coverage also provides an extended range and thus a longer warning time for some aircraft (depending on flight path).

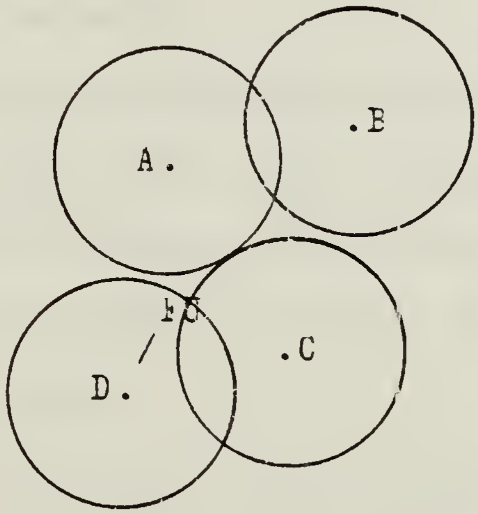


Figure 13. Daisy Chain Network of Mod A FAARs

b. Mod B FAAR

The second modification to the FAAR was based on a design approach to:

- o replace the original range gated doppler receiver with new digital signal processor
- o provide radio frequency (RF) filter selection to change RF and eliminate manual filter substitution.

This was accomplished by replacing the radar receiver in the Mod A by a new digital receiver which resulted in the Mod B.

The Mod B has a 30/60 km selectable feature and provides hovering helicopter detection/classification. Its

increased signal to noise ratio improves its ECCM capability along with the variable low velocity cutoff for road traffic, rain, and/or chaff rejection. [Ref. 11]

c. Improved Target Alerting Data Display Set

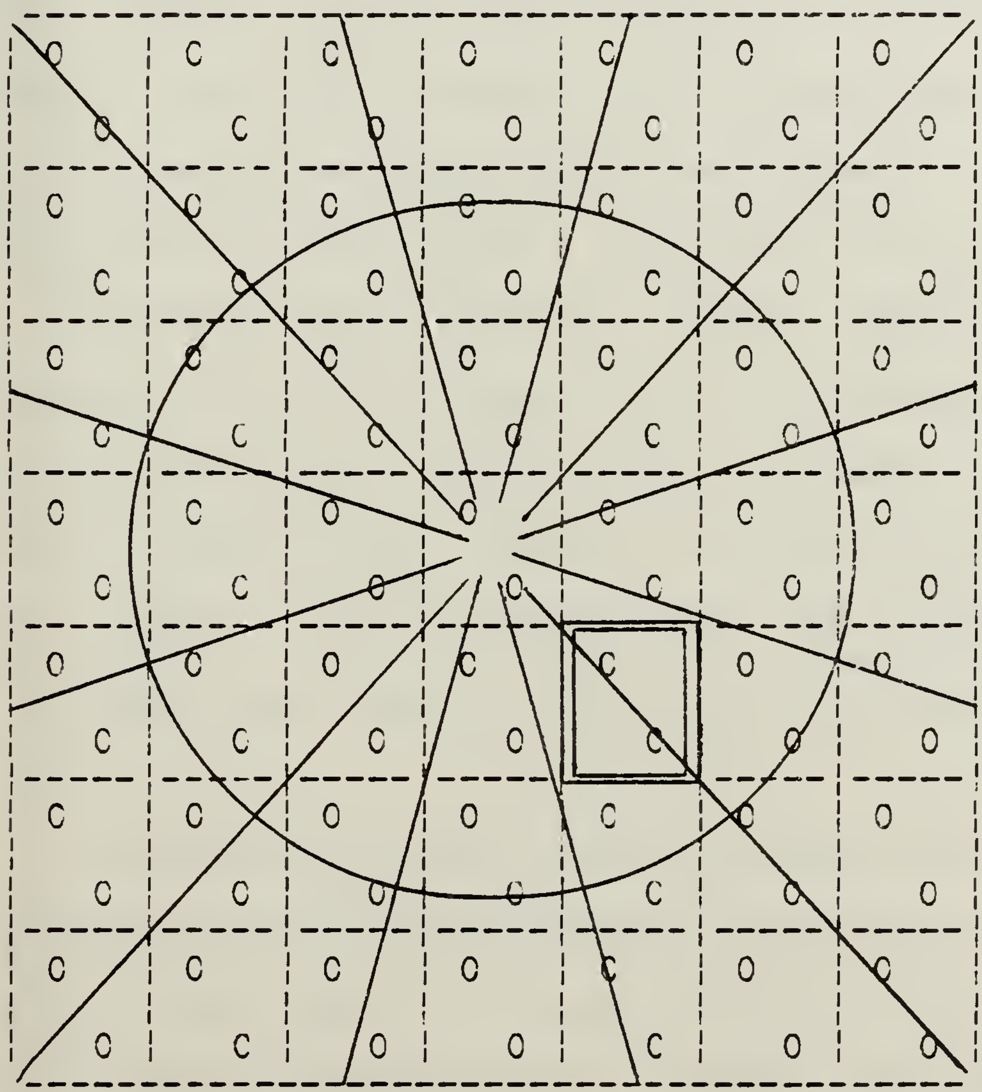
The design approach to correcting TADDS deficiencies included:

- o providing a weapon-centered display
- o using IFAAR data link message
- o provide alerting for potential targets
- o provide cueing accuracy to targets within weapon system range
- o retain the high dollar items of the basic TADDS.

Four of these approaches were met by replacing some internal circuit cards to handle the new data format and by replacing the front panel. [Ref. 11]

Coordinate switches on the panel permit the user to input his location which provide the reference required for a weapon centered display. Alerting is accomplished as it was with the standard FAAR/TADDS. The cueing function, however, is not satisfied, dispite an attempt to reprogram the display drives. The display was programed such that the tracks in ranges of 1.5 to 7.5 km of the weapon system were displayed with more accuracy in the 16 boxes inside the circle (3x3 km=9 sq km/box) while the boxes outside the circle remained as in the basic TADDS (5x5=25 sq km/box) (see Figure 14).

Figure 14 also depicts the ambiguity problem with the ITADDS and the inability to cue the fire unit. The large circle encompasses the desired cueing area and the radial lines delineate 30 degree sectors. Each of the 48 boxes (exclude center box) contains two flippers: one is orange to indicate unknown aircraft, the second is green to indicate friendly aircraft. The ambiguity occurs when a flipper in a box that straddles two sectors is signaled.



0 - indicate friendly/unknown flippers

Figure 14. ITADDS Display

Instead of indicating a 30 degree sector, this indication alerts the fire unit to a track that could be anywhere within a 60 degree window. Therefore, cueing to less than 60 degrees is not possible with the current display.

d. Integrated Weapons Display (IWD)

To utilize the accuracy of the IFAAR and to overcome the cueing deficiency of the ITADDS, Sanders developed an IWD. The IWD utilizes a processor to integrate radar target data with forward looking infrared (FLIR) data on a common weapon centered night Chaparral display. Both radar symbols and FLIR images on the display move with the turret as it slews in azimuth while the gunner's boresight remains centered on the display. The symbols provide target location, tentative identification, speed, direction, and classification (rotary or fixed wing). Filtering of target information is provided to display only targets which are engageable or threatening (based on aircraft profiles) to the weapon system. Additionally, the IWD presents air defense warnings and weapon control status on the display. [Ref. 11]

Though this system proved extremely accurate and allowed gunners in the May 1982 Golden Blade exercise to get missile tone on the correct target without ever looking outside the turret, there are two problems that need to be addressed. First, the IWD is practical on turret mounted systems such as Chaparral, Vulcan, and DIVAD, but not for

the Stinger (MANPADS). Second, is the doctrinal problem which requires the fire command to be given by the fire unit leader and not the gunner.

3. <u>External</u>

The areas considered external to the battalion include HIMAD or Air Force centers, the DAME, and brigade LNCs. This portion of the Sanders system has received the lesser amount of attention. However, a modification to the current system that has been proposed includes the use of an integrated weapons display (IWD) with a larger (10 inch) plasma display or a cathode ray tube (CRT) display for use in the DAME, SHORAD TOC, and brigade TOCs. The display is capable of depicting SHORAD units as well as current air traffic. This capability (with CRT) was demonstrated in the May 1982 Golden Blade exercise, and provides management and liason personnel with a real-time "picture" of the airspace while providing a less responsive view of the SHORAD coverage. (Fire unit locations are updated manually.)

There is currently no means for passing data automatically between HIMAD or Air Force and the SHORAD system. That exchange, utilizing the air defense coordination section (ADCS) at the HIMAD unit, will continue to be alerting only by voice tell. An IWD with large screen can be provided to the ADCS for information only, since no means of incorporating HIMAD tracks into the SHORAD system have been explored.

B. LITTON PROPOSAL

1. <u>Overview</u>

Like Sanders, Litton did not attempt to design or develop a total SHORAD-C2 system. Their approach was to concentrate on data processing and displays while utilizing available sensor data from either FAAR, IHAWK and/or AN/TSQ-73. As shown at Figure 15, the system description will be given in two portions, internal and external to the SHORAD battalion.

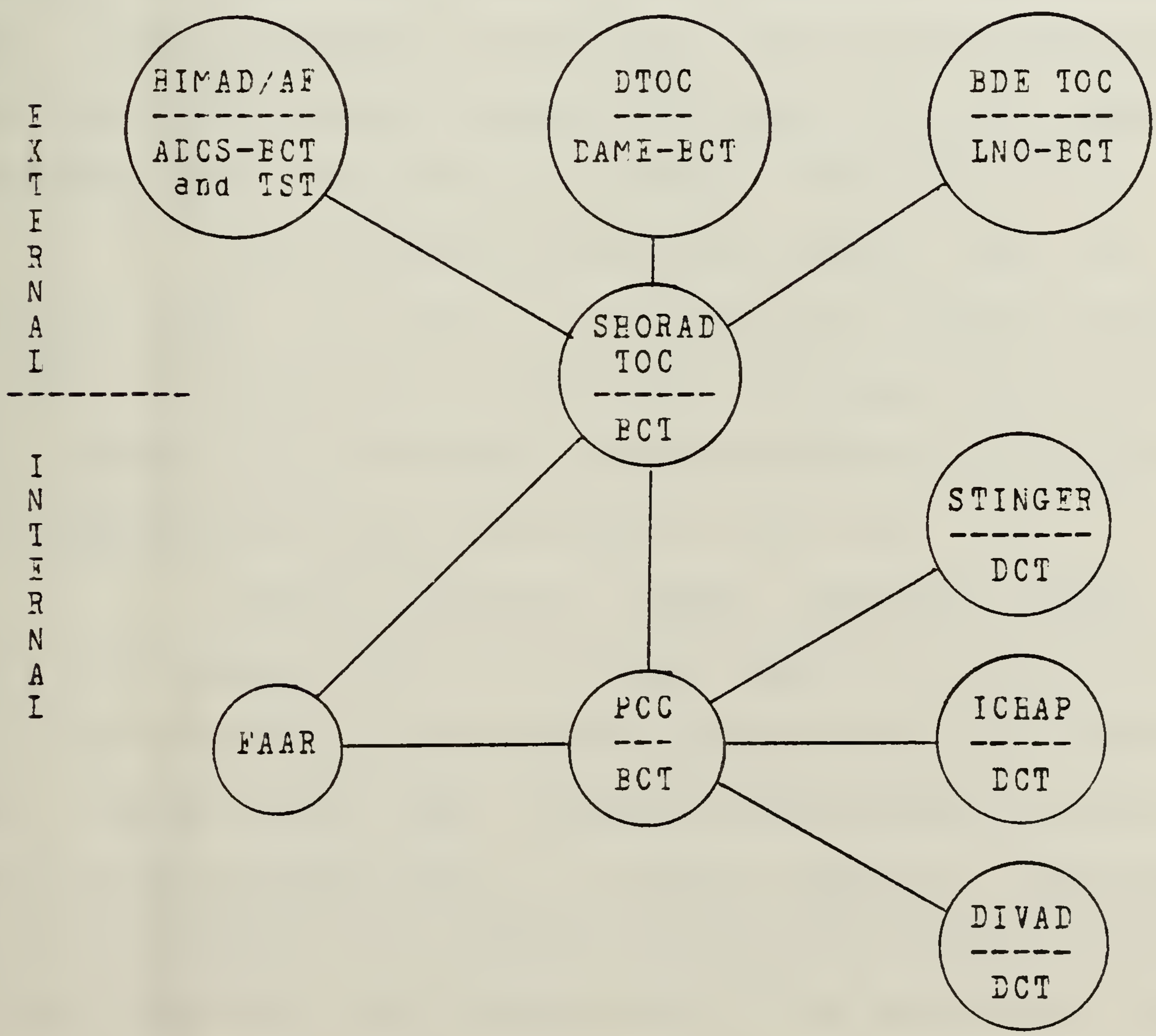


Figure 15. Litton SHORAD-C2 System Design

2. Internal

Two pieces of additional equipment comprise the hardware needed within the SHORAD battalion to provide both early warning and command and control to the fire units. These additions negate the need for the TADDS or the improved TADDS.

a. Digital Communications Terminal (DCT)

The DCT is a hand held "smart" terminal with alphanumeric and graphics capability which allows the display of maps, air corridors and prohibited areas, as well as control procedure information. This secure, high speed two-way communication device interfaces with all standard military radios and secure equipment. [Ref. 12: p. 7]

Its first air defense application was for the Marine Corps in 1977 as an interactive display terminal (IDT). Subsequently, it underwent development for the Army to comply with the Missile Interim Specification Standards for SHORAD Data Link (MIS 34585A). [Ref. 13]

The DCT provides a weapon centered display of the air picture within selectable ranges of 5, 10, or 20 km of the fire unit. This feature provides for both alerting and cueing since high resolution is provided on close in fast moving targets while a lesser amount of resolution alerts operators to slower moving and/or distant targets (see Figure 16). Two resolutions, and therefore update rates, were incorporated to allow message traffic to be sent

from the fire unit while the slower data rate is in use. [Ref. 12: p. 19]

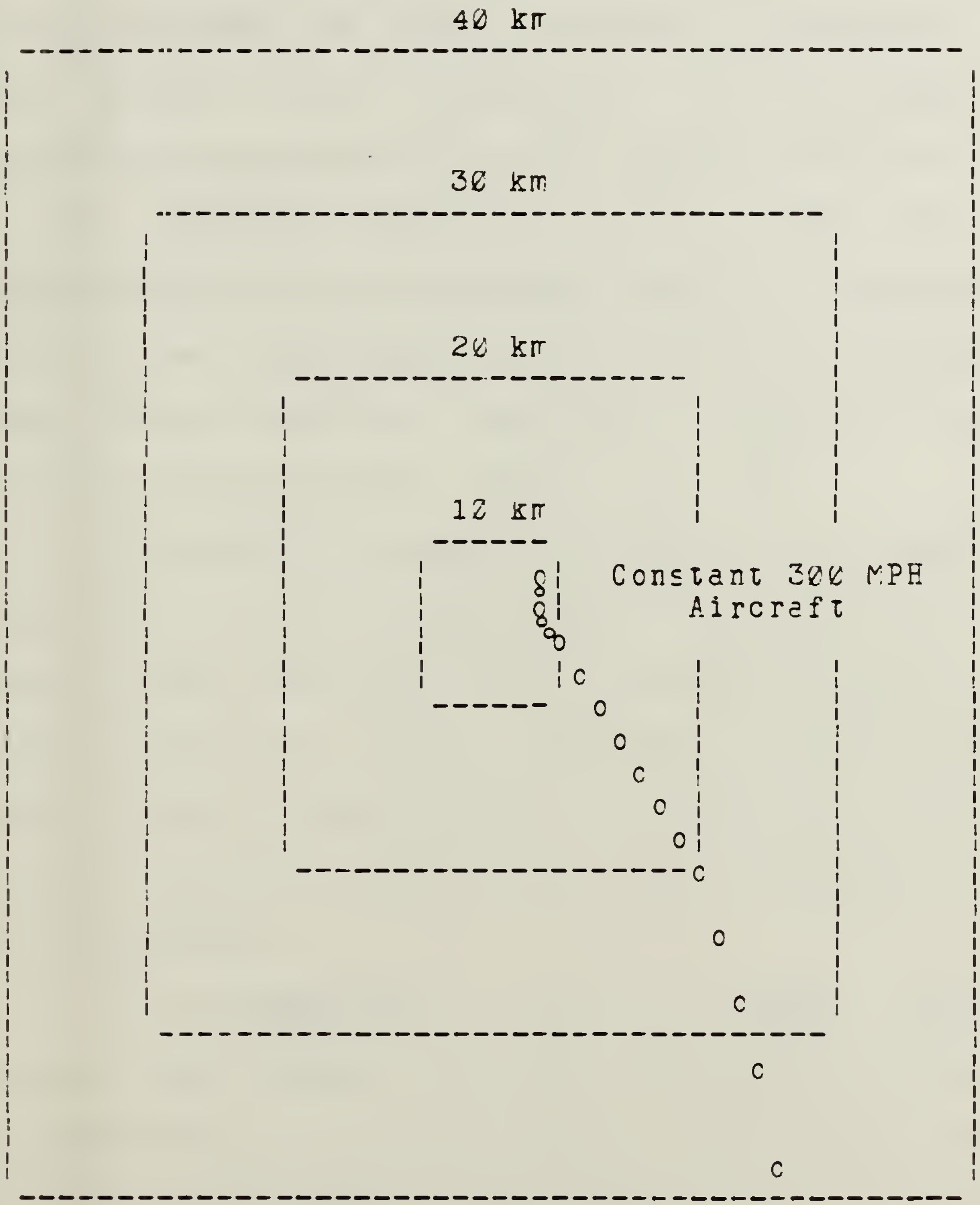


Figure 16. Resolution Adapted to Threat Situation

b. Briefcase Terminal (BCT)

The briefcase terminal is a lightweight, portable, intelligent communications and display terminal that was designed to help commanders coordinate troop actions quickly and efficiently. It is capable of simultaneous communication over six separate radio or wire nets and presents commanders with a 12x4 1/2 inch interactive alphanumeric and graphic display. Additionally, there are three input/output ports that may be connected to ancillary devices such as a digitizer, keyboard, printer, and/or mass storage devices. [Ref. 12: p. 15]

The BCT is required to perform the integration of sensor data prior to transmission to the fire unit DCTs. As shown at Figure 15, BCTs would be located at several key command and control centers throughout the air defense battalion. Some of those centers would require a digitizer (ie. data tablet) to permit manual input of graphics for a variety of reasons.

(1) <u>SHORAD TOC</u>. The air defense operations officer at the SHORAD TOC would use the BCT to integrate sources of track and control procedure data that is external to the battalion prior to down-linking appropriate data to other BCTs and/or DCTs throughout the division. It would also uplink the organic sensor (FAAR) data and fire unit status to interested command centers. The BCT at the SHORAD TOC would be equipped with a digitizer to allow graphical

[illegible]

input to all SHORAD users. This TCC, with the BCT, would provide the link between the internal and external users of air defense command and control information.

(2) <u>Platoon Command Center (PCC).</u> The PCC requires a BCT to integrate local sensor (FAAR) data with the down-linked data from the SHORAD TOC. The integrated picture is then transmitted to local fire units. The PCC would uplink the local data to the SHORAD TOC to complete the exchange of data. The BCT at this center would not be equipped with a digitizer as the platoon would not initiate messages requiring graphics.

2. <u>External</u>

As depicted in Figure 15, the functions that are external to the SHORAD battalion are the division airspace management element (DAME), the HIMAD or Air Force control center within or closest to the division area, and the supported brigade TOCs with air defense liason officers (LNOs). One piece of additional equipment, described below, is needed to properly interface with the HIMAD equipment. The briefcase terminal, however, meets all of the other integration needs.

a. Division Airspace Management Element (DAME)

The DAME must be equipped with a BCT to monitor the airspace situation and to transmit control procedure information received from the Air Force liason officer in the DTOC. Though this may not be the primary method for

disseminating status changes, it provides an alternate/back-up. A digitizer would be required to allow DAME personnel to down-link air corridors, restricted areas and main supply routes to the SHORAD TOC for further dissemination.

b. High-to-Medium Altitude Air Defense (HIMAD)

There are several potential sources of long range track data, which include the IHAWK acquisition radar, AN/TSQ-73 and Air Force control and reporting center (CRC) radar. Since these systems do not produce the same message format as that required by either the BCT or DCT, Litton developed the transmission scheme translator (TST). The TST has demonstrated the ability to covert TADIL-B format (used by IHAWK and AN/TSQ-73) into burst transmission format for down-link. The original design objective was to allow for conversion of ATDL-1 format as well, however, to date that capability has not been demonstrated. [Ref. 14]

The conversion and transmission process create a delay between sensor acquisition and user receipt. Alerting can be accomplished, since the total transmission time for HIMAD tracks to the SHORAD fire unit is about ten seconds. This delay, however, prevents the HIMAD sensor from cueing SHORAD users.

The air defense coordination section (ADCS), equipped with a BCT, would provide direct access to the SHORAD-C2 system with control procedure changes. In

addition to providing long range track data to SHORAD units, the ADCS could provide SHORAD sensor data to HIMAD. No means for conversion of burst transmission to TADIL-B for automatic input to the AN/TSQ-73 or battery control center of the IHAWK unit have been addressed, but the BCT display could provide for a visual comparison with HIMAD displays.

c. Brigade Liason Officer (LNO)

The brigade LNO, with a BCT and digitizer, is able to keep the brigade commander informed of the air-battle as well as influence SHORAD deployment in support of the land battle. The memory capability in the BCT offers the ability to determine historical avenues of approach and attack profiles. Special air operations and friendly close air support can be protected by adequate, yet not excessively long, hold fire periods.

V. COMPARATIVE ANALYSIS

The constraints and associated criteria of chapter three have been organized into three basic categories: fielding requirements, physical requirements, and performance requirements. Each category will be addressed in matrix form with detailed explanation following any system that is unable to meet any criteria of a given constraint or where the capability is uncertain.

TABLE IV

RISK LEVELS

LEVEL	STATUS	RISK
1	Operational System	Zero
2	Modify Existing Capability (No New Features)	Slight
3	Increase Capability (Add New Feature/Proven Principle)	Moderate
4	Laboratory Tested(Breadboard)	Substantial
5	Theoretically Possible (No Experimentation Done)	Very High

Any uncertainty or risk rating will be further qualified by the use of risk levels found at Table IV. These levels are designed to assist the reader in determining the degree of risk involved for a particular criterion.

A. PERFORMANCE REQUIREMENTS

TABLE V

PERFORMANCE REQUIREMENTS

	Constraints	Sanders	Litton
	Sensors networked or processors consolidate data	YES	YES
	Alerting provided to fire units	YES	YES
(1)	Cueing provided to fire units	PARTIAL	YES
(2)	Air battle pict. to DAME, BDE TOC, and SHORAD TOC	PARTIAL	YES (RISK) (LVL-2)
(3)	C2 required to engage A/C at the fire unit	NO	YES
(4)	Acknowledge C2 receipt at F.U.	NO	YES
(5)	Integrate with DIVAD sensor	YES (RISK LVL-3)	YES (RISK LVL-3)
(6)	Integrate with HIMAD source	NO	YES

Note (): Numbers correspond to explanations below.

1. Cue Fire Units

Sanders' proposal meets this requirement whenever the integrated weapons display (IWD) is a part of the weapon system. The Stinger systems, the majority of air defense weapon systems in the division area, will not be cued.

These systems do not have the IWD and rely solely upon the ITADDS for early warning. Some fifty-eight percent of the SHORAD weapon systems would not be cued.

2. Air Battle Picture

The Sanders proposal received a partial rating here because of the nature of information provided to the various command centers. This design offers only the current air traffic, requiring continuous monitoring to retain any historical data concerning trends, avenues of approach, and/or enemy target priorities. There is no capability for storing track data on an hourly, daily, or weekly basis. There is also no means to determine which fire units are operational at any one time, nor is there a capability to receive long-range track data from HIMAD or Air Force sources. The air battle picture offered to the DAME, SHORAD TOC, and Brigade TOCs is, therefore, only the real-time air traffic provided by IFAAR and none of the specified elements of this criterion.

Though Litton's proposal does theoretically provide all of the required capabilities in this area, it is important to remember that all of these features have not been demonstrated and/or tested. It is a fairly simple task to provide some of these features, warranting a risk level of two, but it takes more time to test and evaluate during this time critical process.

3. <u>Command and Control at Fire Unit</u>

The current voice-tell system, over the command net, is the only way to transmit all of the required procedural data to the fire units under the Sanders design. There is no message transmission capability. Once received by the fire unit, some of the key procedural control words can be manually inserted so as to be displayed on the IWD for ready reference by the gunner. Again, this capability exists only with system equipped with the IWD.

4. <u>Acknowledge Receipt</u>

Similarly, there is no acknowledge capability beyond the current system today. It is a very time consuming procedure to pass all of the required command and control information needed to engage aircraft to all fire units and an even longer ordeal to insure 100% receipt via an acknowledge report. Were receipt and acknowledge of control procedure changes the only task of a fire unit, the total time to complete the loop may be acceptable, however, the reality is that there are many activities going on simultaneously that compete for the command net as well as the fire unit member's attention.

5. <u>Integrate with DIVAD System</u>

Neither proposal has demonstrated the capability to integrate with the DIVAD display. Both systems are able to receive track data from the DIVAD sensor and pass it on to interested fire units, however, the reverse is not a current

capability. Both systems would rate a level three risk here as the sending of compatible data to the DIVAD display may differ substantially from receiving it. Since the DIVAD is still in the development phase, the capability should be incorporated to allow transfer of target data in both directions with which ever SHORAD-C2 system is selected.

6. Integrate with HIMAD

Sanders has done little towards integration with elements outside of the SHORAD battalion. The voice-tell procedure by liason personnel at the HIMAD source would continue to be the means for long-range alerting. Litton, on the other hand, has developed and tested the transmission scheme translator (TST) to perform that very task.

B. FIELDING REQUIREMENTS

TABLE VI

FIELDING REQUIREMENTS

	Constraints	Sanders	Litton
	Capable of world wide operations	YES	YES
(1)	Field by '85-'86 timeframe	YES	YES (RISK LVL-3)
	Compatible with AN/VRC-12 series and HF radios	YES	YES
(2)	Compatible w/ all division types	NO	YES

Note (): Numbers correspond to explanations below.

1. Field System By 1985-1986 Timeframe

The risk rating for Litton is based on the lack of testing on the briefcase terminal (BCT). It would rate a risk level of three. Only the digital communication terminal (DCT) and the transmission scheme translator (TST) have been military specification and operationally tested by both the Marines (in an air defense application) and the Army (in a field artillery use). The BCT was not pursued by the Marine Corps and never tested for specification compliance or for operational capability. This piece of equipment, therefore, may delay the fielding process to complete testing. Though the adaptation of the BCT to meet all of the requirements may seem well within hand, it is important to note that the SHORAD-C2 system proposed by Litton currently has more instruction lines in its software than does the AN/TSQ-73, Missile Minder, system that supports HIMAD today.

2. Compatibility With Type Divisions

Sanders proposal has a shortcoming with this constraint. The display is too heavy (15 lbs.) for the light (straight leg) infantry and airborne soldiers to carry. It may be true that many operations utilizing the light infantry will allow for vehicles for the Stinger teams and towed Vulcan sections, however, Stinger team deployment for these type divisions does not guarantee the use of vehicles. Additionally, should an airmobile or airassault

operation take place, the FAAR would be left behind for insertion at some later time. This situation would leave the fire units with only the current system of slow voice-tell early warning provided by HIMAD.

C. PHYSICAL REQUIREMENTS

TABLE VII

PHYSICAL REQUIREMENTS

	Constraint	Sanders	Litton
(1)	Lightweight display at the fire units	NO	YES
	Display powered by standard sys.	YES	YES
	Easy to operate display	YES	YES
(2)	Mobile sensor	YES	NO
(3)	Survivable as supported units	YES	NO
	Transportable by road, rail, sea, and air	YES	YES

Note (): Numbers correspond to explanations below.

1. Lightweight Display

The improved TADDS is, by size and weight standards, the same as the basic TADDS. Its fifteen pounds makes it extremely unlikely that it will be carried into battle in a dismounted configuration. The weight also would preclude

either the section/team leader or the gunner from carrying it with him during routine duties around the fire unit position. The TADDS today is typically set up at an observation post location upon arrival at a new fire unit site, but left unattended for varying lengths of time during the course of the site occupation. The section/team leader normally has several duties to accomplish during set-up and break-down of the site, as well as throughout the occupation.

2. Mobile Sensors

The current configuration of FAAR, mounted on a gama goat, has proven unsatisfactory for reasons previously discussed. Sanders has developed a new IFAAR to be mounted on a M577 armored vehicle which would afford a greater degree of both mobility and survivability on the battlefield. The LAADS that was sold to Isreal is mounted on a 2 1/2 ton cargo truck and offers greater mobility with a lower probability of vehicle turn-over. (There have been thirty-two vehicle turn-overs with the gama goat mounted FAAR.)

There are advantages and disadvantages to either alternative that need not be addressed here. The fact remains that with respect to the requirement for a mobile sensor, Sanders has addressed the problem and developed both a wheeled and a tracked version for use with appropriate division types. Litton, however, has been content to

utilize whatever sensor is available. The basic FAAR, with its limitations/vulnerabilities, is the current sensor.

3. Survivable

Both proposed systems offer adequate survivability in their respective displays, however, the sensors fall under the same reasoning as above. The armored chassis, into which the Mod B IFAAR can be mounted for the heavy divisions, would offer protection from small arms fire and shrapnel. Should a comparison be drawn, using electronic counter measures (ECM) as an element of survivability, there are several ECCM advantages with the IFAAR that would result in a better rating than the basic FAAR. However, the author is not prepared to conduct ECCM evaluations on specific hardware.

D. COMPARATIVE RECAPITULATION

Table VIII summarizes the results of the comparison as broken out into the three categories. The notation depicts the better system within a particular category without weighting/scaling of groups or criteria within the groups.

TABLE VIII

COMPARATIVE RECAPITULATION

	Sanders	Litton
Performance	-	+
Fielding	-	+
Physical	+	-

E. PERFORMANCE CAPABILITY

Having compared the two proposals using the requirement constraints and criteria, the capability for decreasing total time to engagement of each system should be considered. The SHORAD-C2 system will have no effect on any of the weapon system peculiar actions of the firing sequence once the fire command has been given by the section/team leader. There are two very significant actions that are accomplished prior to the fire command that consume the vast majority of the time in an engagement (regardless of weapon system). They are visual acquisition of the potential target and identifying it as either friend or hostile. These actions equate to the "sense" and "compare" elements of the Lawson command and control process mentioned in chapter one.

The early warning capability of the SHORAD-C2 system is designed specifically to reduce the amount of time required to perform the sensing function. For purposes of this discussion, the visual acquisition function will include receipt of early warning information, search, and detection of the aircraft. Time for this phase starts at the instant a sensor within the SHORAD-C2 system detects the aircraft and ends when the fire unit squad/team leader detects the aircraft.

The identification process will vary in time depending upon range to the aircraft, visibility, aircraft

attitude/profile, aircraft type (helo or fixed wing), and the individual visual aircraft recognition proficiency. The process results in a determination of friend, foe, or unknown. The decision to engage or not is based on the results of the identification process, whether correct or not, and the weapon system capabilities (ie. range limitation).

```
                                                     | Systems|
                  |<----- Acquisition Phase ---->|<Equal->|
                  |                                      |        |
                  |                          |SEARCH &|        |
                  |  EARLY WARNING           | DETECT  |IDENTIFY|
                  +-------------------------------------------+
                  |FAAR           |//////|********|////////|
                  |               |//////|********|////////|
 CURRENT          +-------------------------------------------+
   Sys.           |HIMAD////////////////|********|////////|
                  |    |////////////////|********|////////|
------------------+-------------------------------------------+
                  |FAAR                    |/|********|////////|
                  |                        |/|********|////////|
 SANDERS          +-------------------------------------------+
                  |HIMAD////////////////|********|////////|
                  |    |////////////////|********|////////|
------------------+-------------------------------------------+
                  |FAAR                    |/|********|////////|
                  |                        |/|********|////////|
 LITTON           +-------------------------------------------+
                  |HIMAD         |///////|********|////////|
                  |              |///////|********|////////|
                  +----------|--------------------------------+
              -30 sec     -15 sec      0       1-10      1-10
                                               sec       sec
                                       EW
                                    Received
```

Figure 17. Time-line Comparison

Figure 17 depicts the two phases mentioned above with the acquisition phase separated into two categories. Search and detection will vary depending upon the accuracy of early warning information and the accuracy of the display device as well as weather, terrain, angle of approach/crossing target, and the amount of air traffic. Identification is aided by the use of tentative identification from the C2 system, but the factors mentioned in the paragraph above create the potential for wide variances in the amount of time for a positive identification.

Table IX provides a comparison of both systems to the current one. Each plus (minus--if applicable) sign indicates a 50% improvement over the SHORAD-C2 system in the field today. Early warning received from HIMAD differs from that received from local organic sensors and is thus listed separately.

TABLE IX

TIME COMPARISON--EARLY WARNING

	HIMAD	Organic Sensor
Current	0	0
Sanders	0	++
Litton	+	++

VI. SENSITIVITY ANALYSIS

There were four requirements which received positive ratings accompanied by a risk factor. Three were under performance while one was a fielding requirement. Were any or all of the areas so indicated not to be realized by that particular proposal, the potential exists for a complete reversal of decision as to which system is the better. Regardless of outcome, the author feels that the exercise is necessary to force the consideration of various eventualities.

With four ratings in question, there are numerous combinations of possible outcomes ranging from the realization of all four capabilities to realizing none of them. Without even considering partial realization of some requirements, which would increase the number of combinations, there are still too many to enumerate here.

The approach, therefore, is to first assume the worst case situation where none of the criteria are achieved and second, to bias the risk ratings against the proposal that appears to be the better system. If neither of these situations alter the findings, no further analysis is warranted.

A. WORST CASE

The tables of requirements and ratings need not be reproduced to show all of the ratings after forcing risk areas into shortfalls. The comparative recapitulation chart (see Table X), however, shows the effect of the four negative ratings. It appears to create the picture of equal systems, with one system having the advantage in performance, the other in physical characteristics, and equal fielding capabilities and/or limitations. A deeper look is required.

TABLE X

COMPARATIVE RECAPITULATION (Worst Case)

	Sanders	Litton	
Performance	-	+	
Fielding	o	o	(no advantage)
Physical	+	-	

There are eighteen criteria within the above three categories of requirements: eight under performance, four under fielding, and six under physical. Assuming all criteria are of equal weight (an assumption to be addressed later), weighting factors of 8/18, 4/18, and 6/18 should be applied to the three categories respectively. That would result in a slight advantage to the Litton proposal.

A more basic approach is to simply add up the total positive (or negative) ratings and determine which system is

better based on the larger (smaller, if counting negative) number. Table XI shows the outcome of this method, with Litton maintaining the advantage. Were partial ratings considered as total capabilities, the difference between systems would be diminished, yet the outcome would be unchanged.

TABLE XI

COMPARATIVE RECAPITULATION

(All Positive)

	Sanders	Litton
Performance	2 (plus 2 partial)	6
Fielding	3	3
Physical	5	4
TOTALS	10 (plus 2 partial)	13

B. BIASED CASE

The most bias situation against the Litton proposal would result in all three risk categories receiving negative ratings while the Sanders proposal is assured to achieve success in their risk area. The outcome, in Table XII, is less decided and warrants a look into the assumption of equal weighting among individual criteria.

The order in which the categories of requirements were presented was not random. Though all criteria were considered necessary to an effective SHORAD-C2 system, some

TABLE XII

BIASED RATING TOTALS

	Sanders	Litton
Performance	3 (plus 2 partial)	6
Fielding	3	3
Physical	5	4
TOTAL	11 (plus 2 partial)	13

some of the capabilities are decidedly more important. A system that does not alert fire units to aerial threats, for example, is nearly worthless, while a system display that requires a non-standard nickel cadmium battery may only mildly detract from its appeal.

The majority of performance criteria are considered essential to an automated SHORAD-C2 system. Certainly alerting and cueing are the most basic requirements. Fielding requirements are extremely important though the criteria about the '85-'86 timeframe is less binding than the remaining three in that category. It is, after all, more important to field the desired system with a reasonable delay than a less desirable system exactly on time. (There is room for much discussion on degrees of timeliness and desirability that will not be addressed here.) Finally, the physical requirements are of lesser importance than the first two. There are other means for coping with shortfalls in some of these areas. Training, doctrine, tactics, and planning are some of the factors that field units may modify

to better handle any deficiencies in the physical criteria group.

A subjective weighting may be applied, whereby performance is weighted heavily, fielding weighted even, and physical weighted lightly. Table XIII gives a capsulization, by requirement categories, after weighting has been applied. The figures to be weighted included the biased totals (Sanders' risk rated positive and Litton's risks rated negative) and the partial ratings of Sanders in the positive total for performance. Weighting was done using the net difference per category in the following way: the performance group counted four times, the fielding group counted twice, and the physical group counted once.

TABLE XIII

WEIGHTED RECAPITULATION

	Sanders	Litton	
Performance		++++	(heavy)
Fielding	o	o	(even)
Physical	+		(light)

The capability gap is narrowed considerably by biasing the ratings, however, the advantage is still apparent. No further analysis is required since the most damaging occurance to the system that more closely meets the desired capabilities does not alter the outcome.

VII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The need to correct SHORAD-C2 deficiencies was identified against the backdrop of the Soviet air threat and the Division '86 air defense assets. The command and control system needed to perform two major functions: provide early warning to SHORAD fire units, and provide "improved" means for weapon system control. The SHORAD-C2 office of the directorate of combat developments (DCD) at Ft. Bliss, Tx. assisted in the development of a list of constraints and criteria for the automated C2 system.

Information was made readily available by the respective companies to allow for adequate description of components and capabilities of the Sanders and Litton equipment. The system design, based on equipment capabilities, was done by the author to allow for complete system comparison. The comparison that followed utilized categories of requirements to group ratings and subsequent discussion of the respective system failures (or near failures) to meet stated criteria.

Finally, the system that more closely adhered to the stated criteria was subjected to biased ratings. This removed questions about the impact of risks associated with several criteria and negated the need for further analysis. The most desired system was apparent.

B. CONCLUSIONS

Analysis of the two proposals produced the following conclusions:

- o The Litton proposal has the better ratings based on the comparison of all stated criteria.
- o The Litton system is strong in the areas of local processors and displays while Sanders concentrated on radar improvements and networking the radar data together.
- o There is only one criterion (integration with DIVAD) in which both systems are deficient reflecting the different approaches to the SHORAD-C2 complexities.
- o The Litton proposal does provide fire units with increased time available to perform the visual acquisition and aircraft identification functions prior to the decision to engage.

C. RECOMMENDATIONS

- o Due to the diverse paths taken by the two companies involved, it is recommended that a hybrid system which incorporates the advantages and overcomes the weaknesses of each proposal be evaluated.
- o Once the request for proposal is released and subsequent proposals are submitted, it is recommended that a similar type analysis be conducted with all

proposals as a more indepth study would consume valuale time needed to field a system within the specified constraint.

APPENDIX A

CRITERIA JUSTIFICATIONS

This appendix will provide detailed explanation as to how the author arrived at each criterion. Several criteria were taken straight out of the letter of agreement (reference 1) that Ft. Bliss, as the user, defined as requirements. Each criteria will be stated, in brief, as part "a" with its justification at part "b".

A. PERFORMANCE REQUIREMENTS

1a. A fire unit (FU) cannot be dependent upon only one sensor.

1b. Taken from the LOA at reference 1, page 2.

2a. FU provided 15km alerting radius.

2b. This figure was arrived at by the author in the following manner:

(1) The maximum range that an individual can detect an approaching target aircraft is ten kilometers. This is with ideal conditions of flat terrain and clear weather and knowing the direction of aircraft approach.

(2) An aircraft approaching at 400 knots will travel approximately one kilometer every five seconds or 5 km/25 secs.

(3) The alerting capability must warn fire units before the aircraft is within that ideal visual acquisition

range (10 km) or lose the potential for engaging aircraft at the maximum range of the weapon system. The twenty-five second buffer (5 km beyond acquisition range) allows for last second crew adjustments and positioning to better prepare itself for searching and possible aircraft engagement.

(4) Alerting gives only gross positional data of aircraft in the fire unit area of interest. Updates will track the aircraft into closer and more accurate positional data, but the initial alert is needed to ready the crew.

3a. Cue FU within 10 degrees and 3 seconds.

3b. Ft. Bliss requirement per SHORAD-C2 briefing entitled ADA C2 System, briefing slide number P2-10-80.

4a. Air battle "picture" to TCC displays must provide FU status, record of previous tarck data, and integration of HIMAD/AF data.

4b. Pages A-1 thru A-3 of the draft LCA require the exchange, processing, and display of command information. It also requires a consolidated "air picture". Based on the authors knowledge of the command functions in the DAME, Bde TOCs, and SHORAD TCC, the stated criteria met the essential elements of information.

5a, 6a. C2 information required by FU to engage A/C, Acknowledge receipt.

5b, 6b. Required by reference 1 pages 1 and 2.

7a. Data must be compatable with DIVAD system.

7b. A requirement established by the author to take advantage of the many sensors that the DIVAD systems offer. For survivability (EMCON) purposes, the DIVAD sensors may (on occasion) be turned off. When this occurs, the SHORAD-C2 track data would be the only means of receiving early warning. In addition, there should not be two separate systems for passing control procedure information, necessitating compatibility between systems.

8a. Integrate long-range data for alerting.

8b. Primarily required for command post purposes, this criterion also allows for local sensors to fill gaps while HIMAD sensors provide long-range data on unmasked targets. HIMAD data may be the only source of data for special (ie. air raid, airmobile, penetration) operations where local sensors can not accompany the weapon system.

B. FIELDING REQUIREMENTS

1a. OT&E for worldwide use.

1b. Reference 1, page A-3.

2a. Field by '85-'86.

2b. To be available for the Division '86 structure and to meet the Ft. Bliss schedule for an interim system before the "Objective" system is available in the 1990's.

3a. Compatible with current and HF radios.

3b. Page A-2 of LCA explains that the new

communications equipment will support the SHORAD-C2. That system will not be available in '85-'86. The SHORAD-C2 system developed now must be compatible with equipment in the field today and the new equipment.

4a. Perform equally in four of the five division types.

4b. This criterion was the authors. It accounts for the mission and equipment differences between division types and allows for slight performance deveation based on equipment availability.

C. PHYSICAL REQUIREMENTS

1a. FU display weigh less than 10 lbs.

1b. Based on paragraph 2a on page A-3, reference 1, the author determined that ten pounds was the maximum that a display could weigh if a Stinger team was to operate dismounted. With all of the other equipment required, this may well be too much, but will act as an upper limit only.

2a, 3a. FU display standard power, easy to operate and weapon centered.

2b, 3b. Reference 1, page 2.

4a, 5a. Sensor must be as mobile as supported unit, survivable as supported unit.

4b, 5b. Reference 1, pages 2, A-3, A-4.

6a. System components deployable by C-130.

6b. Reference 1, pages 2, A-3, A-4.

APPENDIX B

THE DIVISION IN 1986

The Combined Arms Combat Developments Activity's (CACDA) "Division 86 Final Report" of October 1981 is the major source of data for the division structure that follows. That report is paraphrased, summarized, and quoted throughout this appendix. The study included analytical input of the force structure tradeoffs and wargaming conducted by the Combine Arms Center (CAC). "Prior to the division restructuring study (DRS) of 1976, the Army had last reorganized in the mid-1960s as a result of the Reorganization Objective Army Division (ROAD) Study." [Ref. 6: p. 1-1] In 1975 the DRS was directed to develop the optimum size, mix, and organization of the Army divisions for the 1980-1985 timeframe,. based on a need to determine the best use of new weapons that had been fielded and the tactics to maximize their firepower. After months of study and evaluation by various headquarters, the Commander, TRADOC, directed that an operational concept for Division 86 be keyed to the Battlefield Development Plan functional tasks which evolved into the areas depicted at Table XIV with the appropriate proponents. The following paragraphs will describe the results of the study in these functional areas.

TABLE XIV

DIVISION 86 FORCE STRUCTURE FUNCTIONS/PROPONENTS

FUNCTIONS	PROPONENT
Target Servicing	CAC,Inf Ctr,Avn Ctr, Armor Ctr
Counterfire/Interdiction	FA Ctr
Command,Control,Communication	CAC,Sig Ctr,MP Sch
Intelligence/Surveillance/ Target Acquisition	Intel Ctr
Mobility/Countermobility/ Survivability	Eng Ctr,LCGC
Battle Support/Reconstitution	LOGC
Air Defense	ADA Ctr

[Ref. 6: p. 1-4]

A. TARGET SERVICING

Target servicing is the neutralization of enemy forces that are within line-of-sight and are capable of engaging friendly forces with their primary weapons. To service targets may require the seizure and holding of key terrain and may also include the use of supporting weapons. Target servicing in the defense is accomplished by the covering force as well as in the main battle area and when conducting offensive operations.

1. Tank Battalion

The tank battalion is the most potent target servicing unit in the Army. Its cross-country mobility and armor protection provide the shock effect desired. One or

more companies may be cross attached with a mechanized infantry battalion to form a task force that may be supported by one of several units to increase the shock effect. After several draft organizations and studies to determine the optimum mix of companies per battalion and platoons per company, the organization in Figure 18 was adopted by the Chief of Staff for transition into the Army force structure.

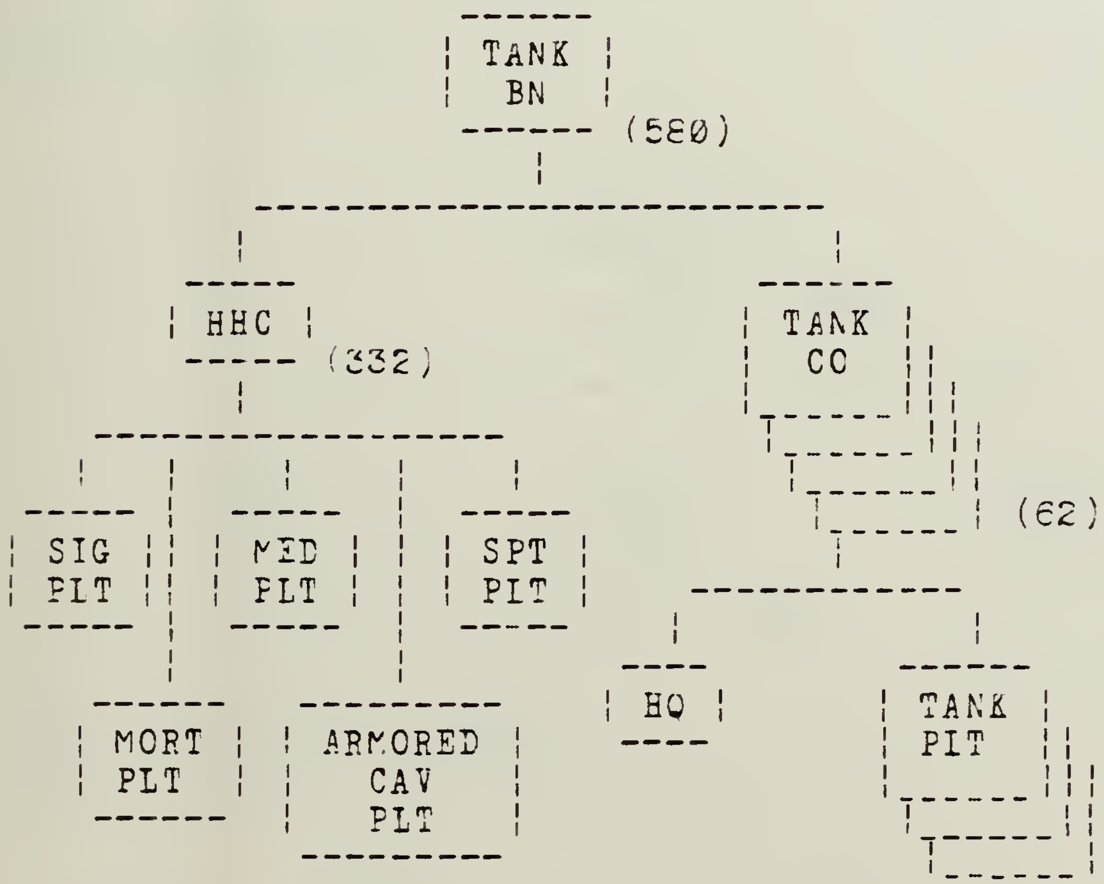


Figure 18. Division 86 Tank Battalion

2. <u>Mechanized Infantry Battalion</u>

The mechanized infantry battalion provides the flexibility to the battalion task force when fighting along

side the tank units or when operating dismounted to hold key terrain, emplace or breach obstacles, repel dismounted enemy attacks, and provide security or locate the enemy by use of patrols, ambushes, etc. The new mechanized rifle platoon has the same organizational structure except for the fact that each squad was reduced from eleven to nine men. The antiarmor company may be deployed in centralized support of the battalion or split into platoons that are attached to rifle companies for more effective command and control in a complex situation.

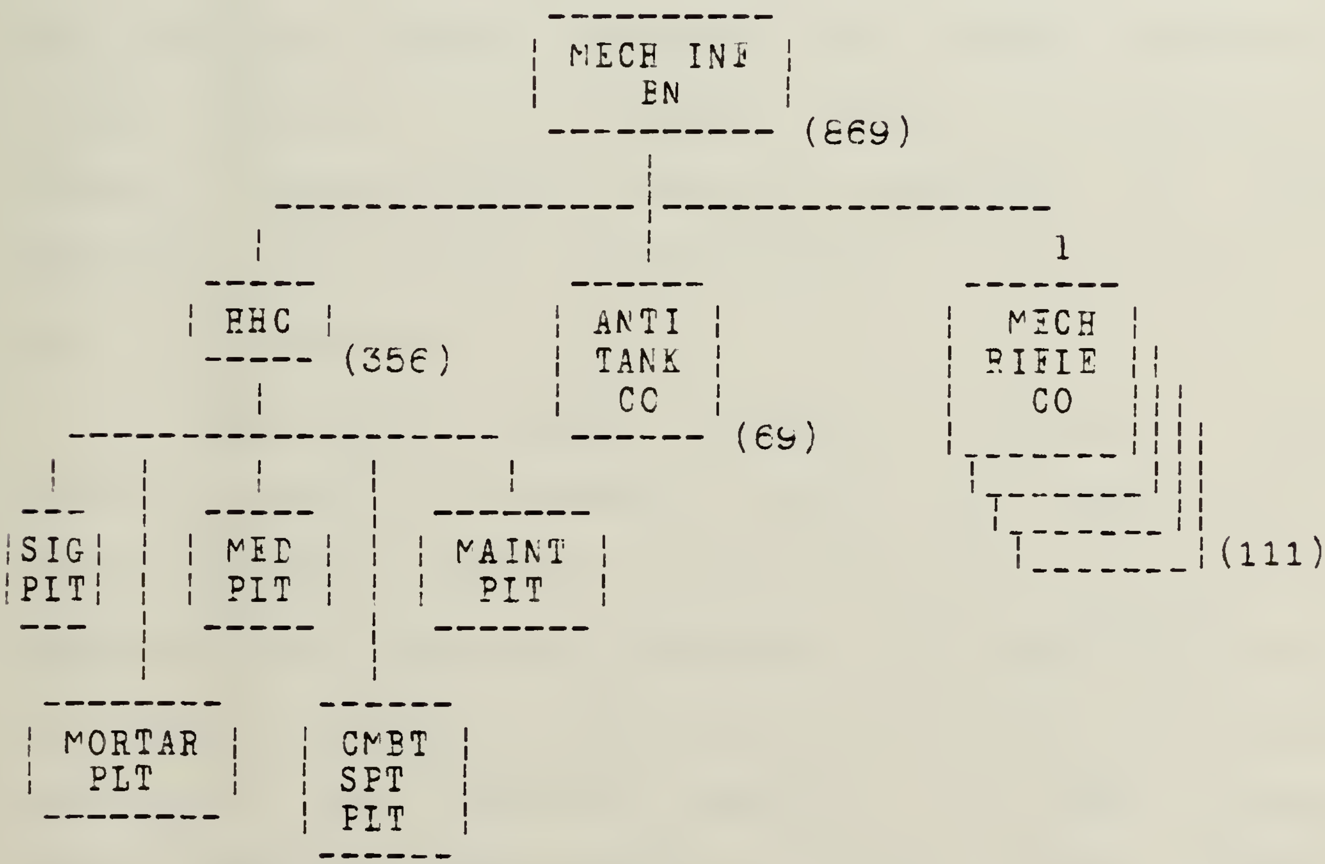


Figure 19. Division 86 Mechanized Infantry Battalion

To maintain symmetry with the four tank company battalion, the mechanized infantry battalion was increased in strength to accommodate four rifle companies. (see Figure 19) In order to stay within the personnel constraints, however, one maneuver battalion was deleted from the division structure leaving a total of ten.

3. Air Cavalry Attack Brigade (ACAB)

The ACAB has a diversity of missions ranging from direct fire on enemy armor and mechanized forces to reconnaissance and airmobile operations. The ACAB also supports aerial logistics operations by providing assets to field artillery aerial observers and combat electronics warfare aircraft. The brigade consists of a headquarters company, a combat support aviation battalion, two attack helicopter battalions, and the division cavalry squadron as shown in Figure 20.

The combat support aviation battalion (CSAB) provides direct and general support to the division by moving personnel, supplies and equipment and by conducting airmobile and/or recovery operations. The CSAB also has the capability to assist in the coordination effort of airspace management. The battalion consists of an HHC, a general support aviation company (GSAC), a combat support aviation company (CSAC), a combat electronic warfare and intelligence company, and a transportation aviation maintenance company (TAMC).

The two attack helicopter battalions (AHB) are the maneuver elements of the ACAB. The mission of these battalions involve destroying enemy armor and motorized forces. Each battalion consists of a headquarters and service company and three attack helicopter companies to be employed in offensive, defensive, and special operations such as rear area combat and raids.

The division cavalry squadron's mission is to perform reconnaissance in front of, to the flanks, and to the rear of the division. This is accomplished thru two ground cavalry troops, two air cavalry troops, and a headquarters troop that includes sensor and NBC reconnaissance platoons as well as a motorcycle platoon. Due to the nature of its mission, this squadron is normally employed by the division headquarters.

```
                              ------
                             | ACAB |(139 A/C)
                              ------ (2344)
                                 |
        ----------------------------------------------------
        |         |                   |                    |
      -----    ------             -------            ----------
     | HHC |  | CSAB |           | AH BN |          | CAV SQD |
      -----    ------  (632)     |_______||          ---------- (557)
     (111)       |                |_______|(522)          |
           ----------------           |               ---------
           |     |    |    |       -------            |        |
        ------   |  ------ |      | AH CO |         -----    -----
       | MIAC |  | | TAMC ||      |_______||       | CAV |  | AVN |
       |(CEWI)|  |  ------ |       |_______||      | TRP ||  | TRP ||
        ------   |         |        |_______|      |_____||  |_____||
               ------    ------                     |_____|   |_____|
              | CSAC |  | GSAC |
               ------    ------
```

Figure 20. Division 86 Air Cavalry Attack Brigade

B. COUNTERFIRE/INTERDICTION

Counterfire is the attack on enemy indirect fire capabilities and consist of target acquisition, processing, attack, and attack assessment. These tasks involve division field artillery as well as Air Force elements that are integrated at the division level. The division artillery (DIVARTY) provides non-nuclear and nuclear fires in support of the maneuver forces and mans the fire support element in the DTOC and division TAC CP. DIVARTY consists of an HHB, a division target acquisition battalion (DTAB), three 155mm self-propelled field artillery (FA) battalions, and a composite general support battalion with a multiple launcher rocket system (MIRS) battery, and two 8 inch howitzer batteries. The 155mm FA battalions are normally deployed in direct support (DS) of a maneuver brigade.

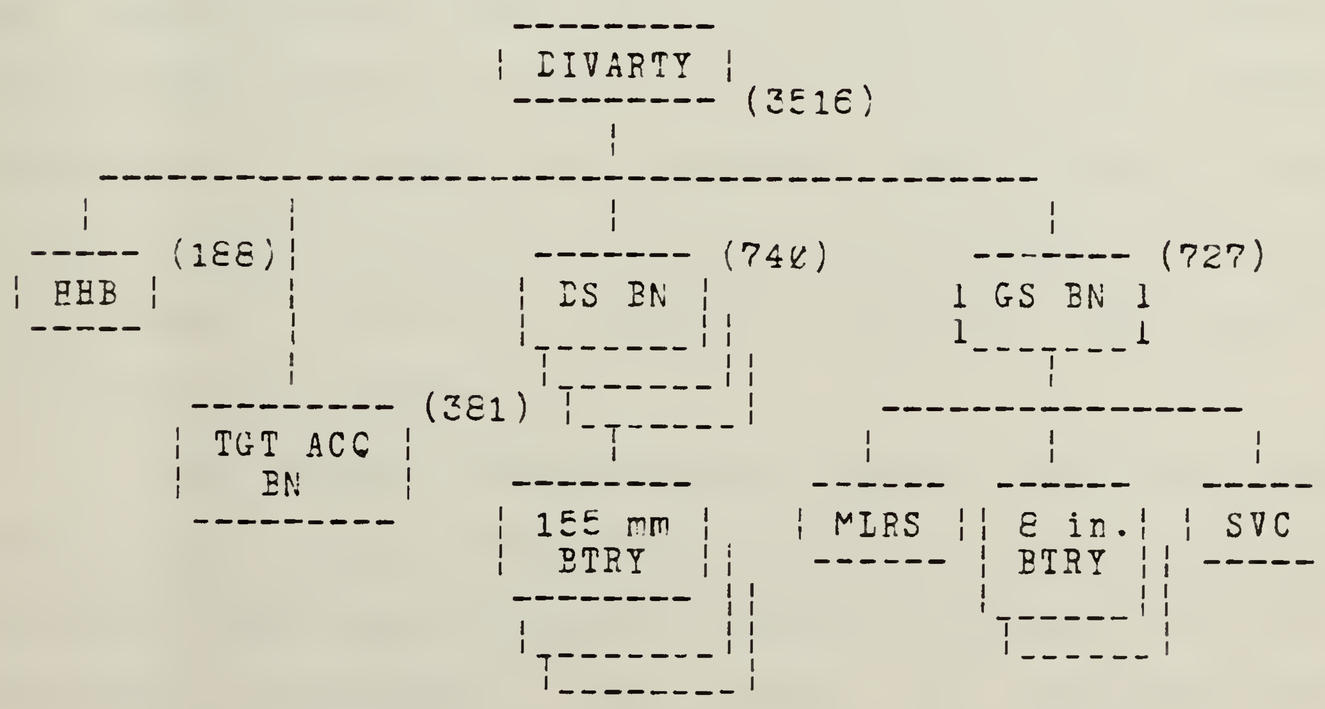


Figure 21. Division 86 Division Artillery

C. COMMAND, CONTROL and COMMUNICATIONS (C3)

Force activities are directed and monitored by use of command and control which includes

> "communications, control centers, and information gathering systems ... to gather and analyze information, plan what is to be done, and supervise the execution of orders." [Ref. 6: p. 4-1]

The three types of units that will be described under the heading of C3 are the signal battalion, the military police company, and the headquarters and headquarters companies at division and brigade.

1. Signal Battalion

The signal battalion is responsible for the installation, operation, and maintenance of a division level communications system. This includes command, control, intelligence, fire control, combat support, and combat service support. The command operations company provides the communications electronics (CE) facilities and services to the DTCC, division TAC CP, and division rear signal centers and provides multi-channel communication to the field artillery brigade, military intelligence battalion, air defense battalion, engineer battalion, and the air cavalry attack brigade.

The forward communications company establishes three area signal centers which each provide facsimile and secure teletype facilities, automatic telephone central office and switching facilities, two secure FM retransmission

facilities, multi-channel communication terminals that link to the division system, and three net control units (one for each brigade signal center) for operating in the division position location reporting system / joint tactical information distribution system (PLRS/JTIDS) hybrid system. The signal support operations company provides a signal center for the DISCOM and DIVARTY and provides multi-channel relays and field cable construction for the division as well as a terminal for multi-channel at the DIVARTY.

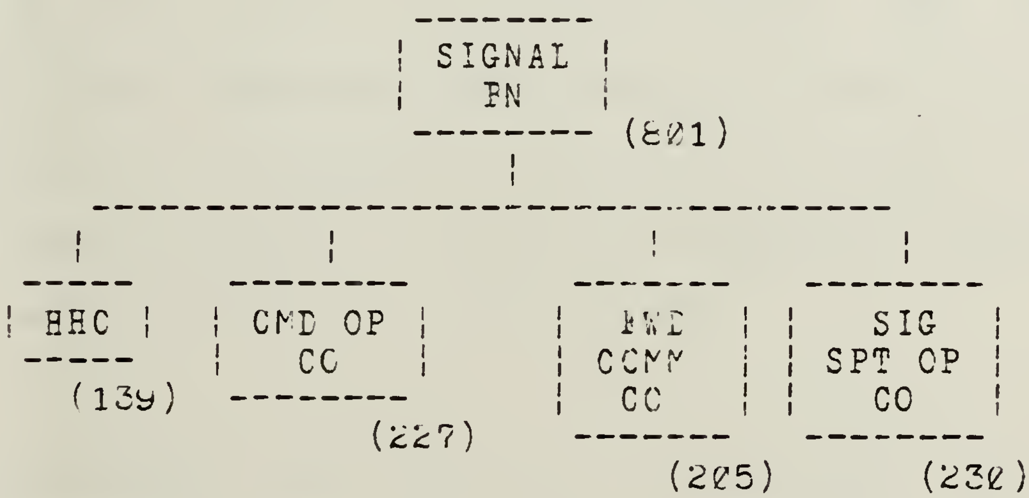


Figure 22. Division 86 Signal Battalion

2. Military Police Company

The military police company will typically operate behind the forward brigades rear boundaries and back to the division rear. The mission includes providing area support to the DTCC, DISCOM, main supply routes (MSRs), all source

analysis center, and to establish enemy prisoner of war collection points. There are three combat support military police platoons to perform movement control, area security, prisoner of war operations, and law and order operation in the division rear.

3. Division/Brigade Headquarters and Headquarters Company (HHC)

The division and brigade HHCs include the staffs that assist in the performance of command and control, staff planning, and supervision of both administration and operation of assigned and attached units. The commanders may be in their respective main CPs or in mobile or tactical CPs where only designated staff personnel deemed necessary to maintain continuity of essential elements of command and control are accessible to the commander.

D. INTELLIGENCE, SURVEILANCE AND TARGET ACQUISITION (ISTA)

ISTA means "locating, classifying, projecting, and providing target information to the commander concerning second-echelon interdiction operations". [Ref. 6: p. 5-1] The division headquarters must plan operations and allocate resources up to 24 hours into the future. While forward elements are in contact and engaging forces from the FLOT to a depth of 15 km, the division interdiction missions affect enemy forces from the FLOT to a depth of 70 km.

The military intelligence battalion (CEWI) is the primary focal point for information concerning enemy rear area forces. In the headquarters and operations company, the all-source analysis center integrates HUMINT, IMINT and SIGINT collections to support target development on enemy activities. The electronic warfare company provides an ELINT collection and locating system, a COMMINT collection and line of bearing data and ECM. A signal intelligence processing platoon provide analyzers of SIGINT data. The intelligence and surveilance company interrogate POWs and provide OPSEC/SIGSEC support. The service support company provides the communications and direct support maintenance on the battalion's organic equipment. The aviation company is under operational control of the CEWI commander and provides command and control for the attached assets, air defense threat personnel to the ASAC, six target acquisition aircraft for MTI radar collection, and six aircraft for COMINT/ESM collection/jamming.

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                          -------
                         | MI BN |
                          ------- (488)
                             |
          -------------------------------- - - - - - -
          |           |           |          |          |
       ------     --------     -------     -----      ------
      | HHOC |   | INTEL & |  | EW CO |   | SVC |    | MIAC |
       ------    | SURVL   |   -------    | SPT |    |(CEWI)|
        (135)    |   CO    |    (125)     | CO  |     ------
                  -------- (103)           ----- (125)
```

Figure 23. Division 86 Military Intelligence Battalion

E. MOBILITY, COUNTERMOBILITY AND SURVIVABILITY

Forces whose mission is categorized as supporting mobility, countermobility and survivability involve

> "operations to keep the tactical forces and logistics moving, deny the enemy ready access to the division operational area and provide for survival of forces and installations vital to division operations". [Ref. 6: p. 6-1]

The two units primarily responsible for performing these missions are the engineer battalion and the NBC company.

1. The Engineer Battalion

The engineer battalion generally allocates the organic units and equipment in support of the maneuver elements. The engineer companies are placed in direct support of each committed maneuver brigade and each company may be augmented by battalion equipment and/or corps engineer equipment and personnel. Each company has a headquarters section, a combat engineer platoon, a mobility/countermobility platoon and a support platoon. The combat engineer platoon is transported by armored personnel carriers and supported by a combat engineer vehicle and two earth movers. The platoons normally operate in direct support of task forces to provide mobility to the combat elements. The platoons are also capable of emplacing explosives or non-explosive obstacles to halt or slow enemy advances.

The mobility/countermobility platoon now has 24 armored vehicles launched bridges (AVLB) to provide mobility

over difficult terrain. The platoon also has the capability to lay and clear mines. The bridge company provides limited crossing capability with the ribbon bridge.

```
                      ------
                     | ENGR |
                     |  BN  |
                      ------ (1083)
                         |
    ----------------------------------
    |              |               |
  -----          ------          ------
 | HHC |        | BRDG |        | ENGR |
  -----         |  CO  |        |  CO  ||
   (136)         ------         |______||| (203)
                  (135)          |______||
                                  |______|
                                     |
                          -----------------
                          |        |       |
                        ------   -------  -----
                       | ENGR | | MOBIL || SPT |
                       | PLT || |COUNTER|| PLT |
                       |______|||  PLT  | -----
                        |______||-------
                         |______|
```

Figure 24. Division 86 Engineer Battalion

2. Nuclear, Biological and Chemical (NBC) Company

The NBC company provides decontamination and smoke support to the division. Smoke is used in both offensive and defensive operations and an NBC center operates the NBC warning and reporting system and provides other NBC data handling services. The decontamination platoons, placed in direct support of each brigade, provide equipment and

expertise in decontamination operations. The smoke platoon is normally employed in support of maneuver elements but may be used in rear area operations as well.

F. BATTLE SUPPORT/RECONSTITUTION

Battle support requires providing committed forces those supplies and services needed to conduct their designated operations. Additionally, such services as medical, graves registration, battlefield recovery, repair and resupply of ammunition and fuel are accomplished. Reconstitution requires rebuilding the force to include people, organizations, command structures and material.

Battle support is conducted at all levels from company thru division from trains areas as well as brigade support areas (BSA) and division support areas (DSA). Some corps units may operate in the DSA. The support concept requires the supporting elements to provide support (to include repair) as far forward as possible and evacuating from forward locating points to the appropriate direct support or general support unit.

The division support command (DISCOM) provides direct support and/or general support to divisional units and consists of a division material management center (DMMC), an adjutant general company, a maintenance battalion, a medical battalion and three forward support battalions. The division data center is a common-user computer system that

assists DISCOM personnel in developing requirements and managing stocks in forward support, supply and transport, aviation and maintenance battalions. It is used to develop and monitor ASL/PLL and assists in the management of division maintenance activities. The DMMC establishes and maintains a centralized property book for all division units.

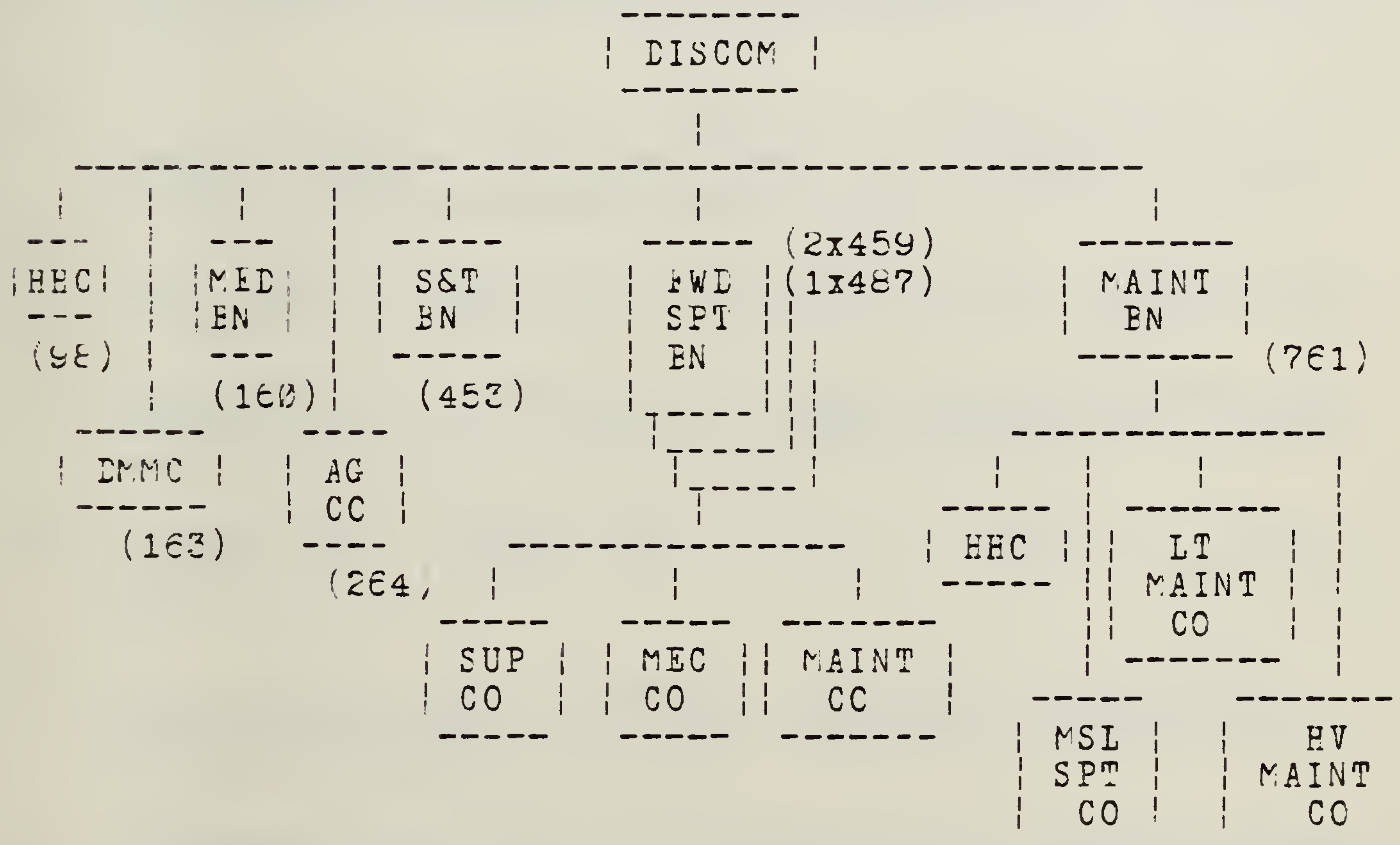

Figure 25. Division 86 Division Support Command

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